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CASCADED TRADEOFFS:

ORIGINAL

A Multiple-Objective, Multiple-Publics Method for Alternatives Evaluation in Water Resources Planning

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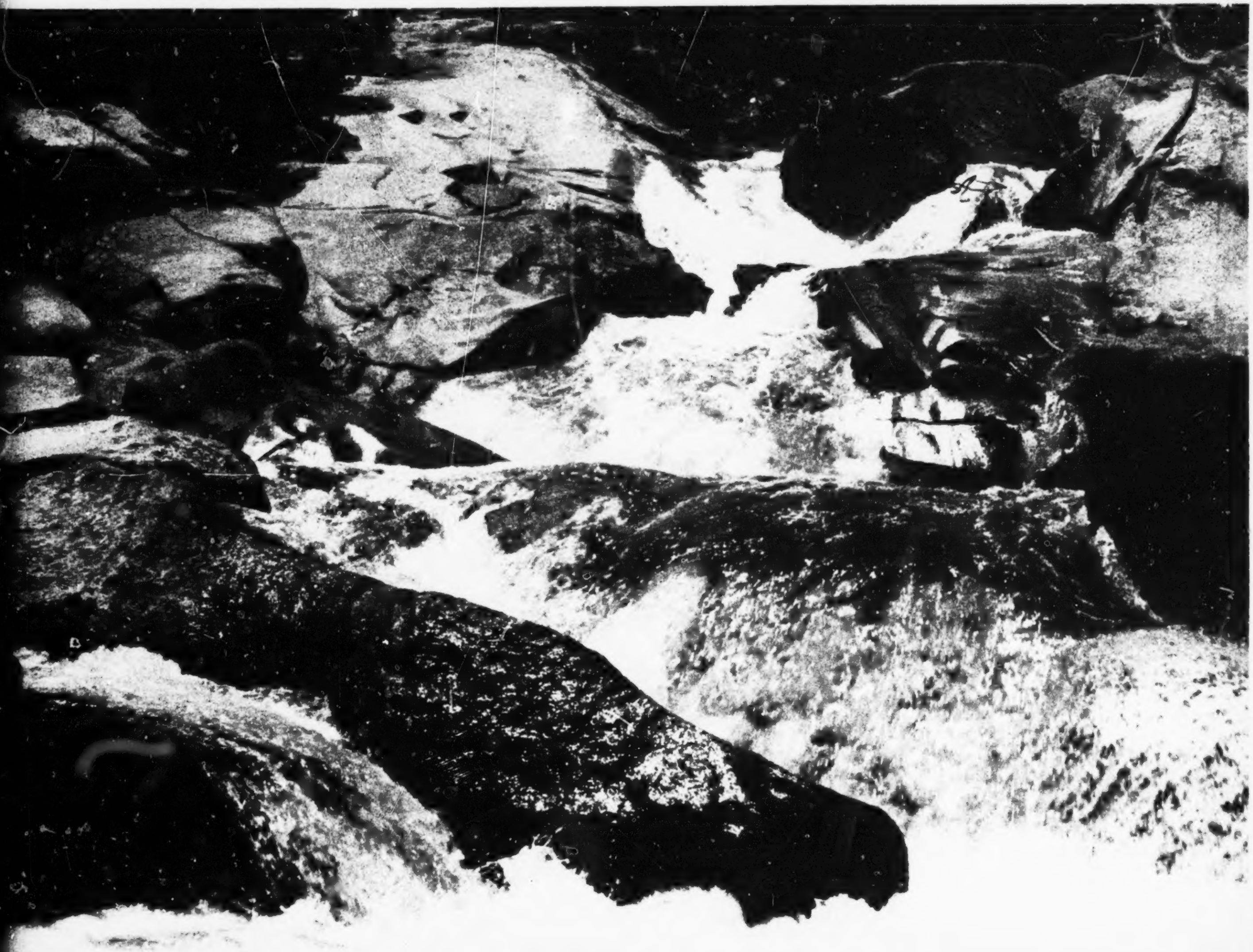

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16. ABSTRACT

Cascaded Tradeoffs is a method for arriving at an overall ranking of planning alternatives on the basis of public values. The key feature of the method is that it provides for making tradeoffs across both issue dimensions and publics. (Traditional economic analyses of market values can be helpful in the first step, but not always in the second. There appears to be no generally applicable alternative to human judgment for comparing the values of different publics.) The method shows not only how to deal with tradeoffs where tradeoffs must be made, but also how to identify or create situations where tradeoffs do not need to be made. In addition, it provides for examination of the extent to which the overall ranking of the alternatives is sensitive to the addition of mitigation measures and to uncertainty in the data.

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in Water Resources Planning

by

Barry F. Anderson

Portland State University
Portland, Oregon

Contract No. 9-01-81-05060

United States
DEPARTMENT of the INTERIOR

Bureau of Reclamation

August, 1981

I

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island Territories under U. S. administration.

In May of 1981, the Secretary of the Interior approved changing The Water and Power Resources Service back to its former name, The Bureau of Reclamation.

"...There are no incommensurables when decisions are made in the real world."

Stokey & Zeckhauser
(1978, p. 153)

PREFACE

This paper is the third in a series that deals with the measurement of public values in water planning studies. The first, logically, if not chronologically, (Brown, Quinn, and Hammond, 1980) deals with general problems of measurement. The second (Lord, Deane, and Waterstone, 1979) focuses more specifically on the problem of *commensuration*, measurement in terms of a common unit properties that are ordinarily measured in terms of different units. This paper is directed even more specifically toward presenting a method for achieving commensuration in Federal water resources planning. Its intended audience is water planners and others who are actively seeking ways to improve the processes by which public policy decisions are made.

The problem of commensuration is central to virtually every complex planning decision. Almost inevitably, gains on some dimensions of impact entail losses on others, and gains for some publics entail losses for others. The problem of commensuration is the problem of weighing these gains and losses against one another in arriving at a decision to recommend one project or policy over others.

The proposed method for dealing with the problem of commensuration is itself necessarily a compromise. Some degree of simplicity has had to be sacrificied in the interests of rigor, and some degree of rigor has had to be sacrificied in the interests of simplicity. Whether the proper balance has been struck remains for water planners, themselves, to judge. It is to be hoped, however, that users will not stop short with the simple judgment that the method is acceptable (with whatever faults it may have) or not acceptable (with whatever virtues it may have), but will go on to seek to improve it. Just as the proposed method builds on existing ones, it is to be hoped that future efforts will build on it, in a continuing process of refinement.

It is my real pleasure to acknowledge the valuable guidance of Darrell Adams, George Wallen, Jay Hokenstrom, Mark Bird, Thayne Coulter, Gail Dishungh, David Duncan, Chris Gelker, and Deborah Saint of the Bureau of Reclamation; William B. Lord of Policy Sciences Associates, Boulder, Colorado; Donald Deane, Gary McClelland, and Thomas Stewart of the Center for Research on Judgment & Policy at the University of Colorado; and especially Curtis Brown, who is associated with both the Bureau of Reclamation and CRJP; and also to thank Kenneth R. Hammond for providing at CRJP a most stimulating atmosphere for learning and thinking about judgment and decision making. Finally, I would like to thank Walter Fruland for editing the final copy, Jan Jones for preparing the art work, and R. E. Long and Adwyn Lim for writing the programs that were used to print out the text.

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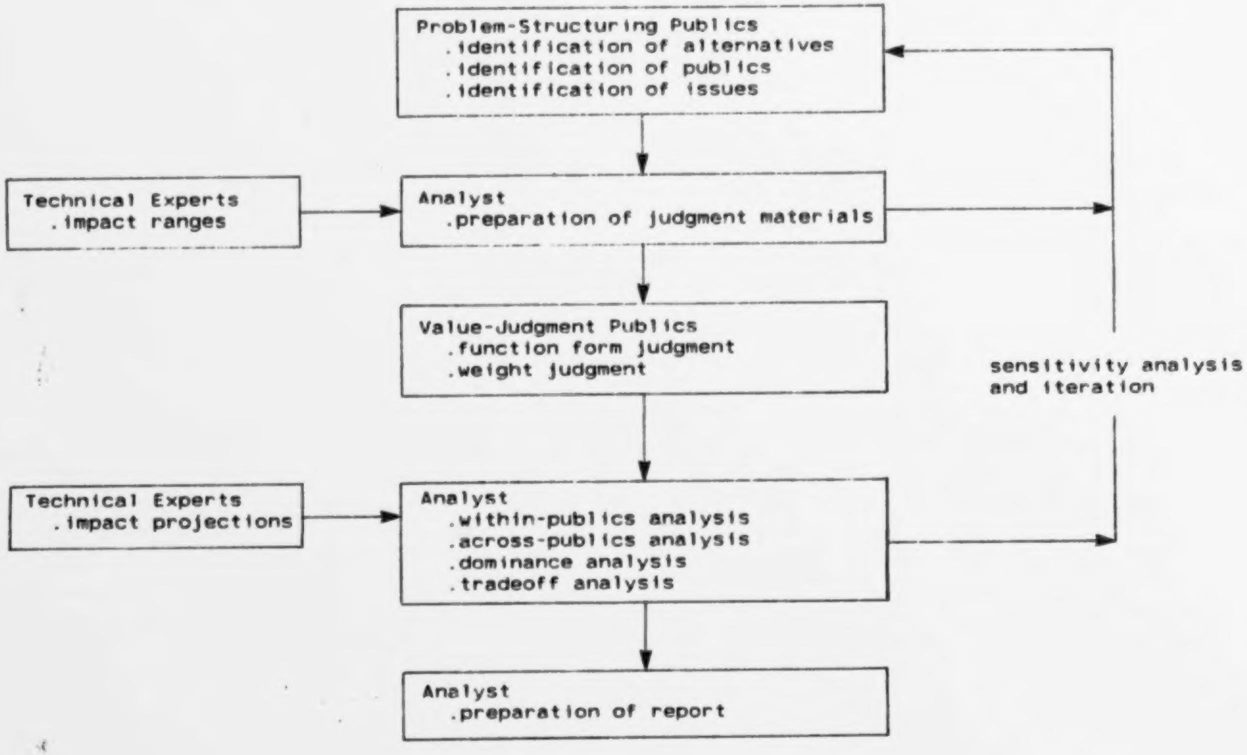
Cascaded Tradeoffs Flow Diagram


Problem-Structuring Publics
.identification of alternatives
.identification of publics
.identification of issues
Technical Experts
.impact ranges
Analyst
.preparation of judgment materials
Value-Judgment Publics
.function form judgment
.weight judgment
sensitivity analysis
and iteration
Technical Experts
.impact projections
Analyst
.within-publics analysis
.across-publics analysis
.dominance analysis
.tradeoff analysis
Analyst
.preparation of report

EXECUTIVE SUMMARY

This paper, which is intended primarily for those water planners and others who are actively seeking ways to improve the processes by which public policy decisions are made, describes a method for arriving at an overall ranking of planning alternatives on the basis of public values. The key feature of the method is that it provides for making tradeoffs across *both* issues, or dimensions of impact, and publics, in a two-step "cascade". It shows not only how to deal with tradeoffs where tradeoffs must be made, but also how to identify or create situations where tradeoffs do not need to be made. In addition, it provides for examination of the extent to which the overall ranking of the alternatives is sensitive to the addition of mitigation measures and to uncertainty in the data.

The key concept is that of *commensuration*. Commensuration is the process of determining what impact on one dimension is equivalent to a given impact on another, or what impact to one public is equivalent to a given impact to another. It is the process of comparing such "apples and oranges" as economic and environmental impacts or impacts to farmers and townspeople. More formally, it is measurement, in terms of a common unit, of properties that are ordinarily measured in terms of different units.

When a choice must be made among plans that have impacts on a number of dimensions or that affect a number of publics, commensuration is usually required by the very logic of the situation. Whenever tradeoffs are involved and a "bottom line" evaluation must be arrived at for each alternative, commensuration can not be avoided. The choice almost always facing planners is, thus, not whether to commensurate but whether to do so well or poorly.

The method described in this paper establishes a scale of commensuration on the basis of value judgments from both representatives of the impacted population and agency decision makers. It begins by identifying publics across which the greatest value differences occur and within which value differences can be assumed to be negligible. Commensuration is then accomplished in two "cascaded" steps: first across dimensions of impact within each public, in terms of the values of that public; then across publics, on the basis of a judgment by agency decisionmakers about a tradeoff dimension. Traditional economic analyses of market values can be helpful in the first step, but not always in the second. There appears to be no generally applicable alternative to human judgment for comparing the values of different publics.

The reader who is interested only in the concept and method of cascaded tradeoffs, and not the supporting methodology, should go directly to Chapter 6.

FABLE

IN the faraway land of FFoedart, during the reign of the good Queen Ursula, three poor farmers, Arnie, Bernie, and Chiswith, rose one day at dawn, had their wives pack them some potato dumplings and oranges and set out for the forest to hunt food for the tables of their poor hungry families.

The sun was well into the sky before Arnie finally spotted something through the brush and pointed. Bernie immediately took aim with his bow. But just then Chiswith stood up, knocked Bernie's bow upward, and sent the arrow soaring over the tops of the trees.

Almost immediately, they heard a great howl of pain, followed by a great crashing down through the trees, and finally a great earth-shaking thud. They found, much to their surprise, that Bernie's arrow had struck and killed a giant ogre who had been lying in wait for the good Queen Ursula's entourage to pass that way. The three poor farmers had saved the good queen's life!

The good Queen Ursula was so grateful, when she learned of what had happened, that she went, herself, to the homes of the three poor farmers and offered each one-fourth of her kingdom as a reward. However, because FFoedart was planted in apples and oranges, each of the farmers had to choose between a fourth that was planted in apples and a fourth that was planted in oranges.

Arnie was distraught. "You can't compare apples and oranges," he said. "There's no way I can choose!" And so he had to decline the offer.

Bernie was more clever. "You *can* compare apples and oranges," he said. "If you have a purpose in mind, you can compare them in terms of how well they suit the purpose. I like to hunt, and oranges have a peel that keeps them clean on hunting trips and enough juice so that I don't have to carry water. I'll take a fourth of the kingdom planted in oranges."

"Oh, no!" said his wife. "I do the cooking, and you can make more things with apples--like apple fritters, applesauce, apple pies, apple butter, baked apples, and applejack. I want our fourth of the kingdom to be planted in apples."

So now Bernie was at a loss for what to do, and he, too, had to decline the good Queen's generous offer.

Chiswith, like Bernie, preferred oranges, and his wife, like Bernie's, preferred apples. But he thought of a way to compare, not only apples and oranges, but also his wife's desire for apples and his desire for oranges.

He said, "If we take a fourth of the kingdom planted in apples, I'll be unhappy, and, if we take a fourth of the kingdom planted in oranges, my wife will be unhappy. But there's another way. If we take a fourth of the kingdom planted in apples and my wife buys me the oranges I want, we'll both be happy; and, if we take a fourth of the kingdom planted in oranges and I buy my wife the apples she wants, we'll both be happy. The only question is: In which case would we be happier?"

Then his wife said, "Either way would be fine with me. As long as I get the apples I need for cooking, I wouldn't mind buying you the few oranges you need for your hunting trips."

And Chiswith said, "Well, that settles it then. I don't care how I get my oranges, but if I had to buy all your apples I wouldn't have any money left for gunpowder!"

So Chiswith and his wife took a fourth of the kingdom planted in apples. Chiswith's wife had all the apples she needed for cooking; Chiswith had all the oranges he needed for his hunting trips, and gunpowder to boot. Because of Chiswith's cleverness, the good Queen Ursula appointed Chiswith Royal Planner. And Chiswith and his wife--and the people of FFoedart--lived happily ever after.

And the motto that Chiswith had carved above the door of the FFoedart Planning Office was this:

> IF YOU WOULD CHOOSE WISELY, YOU
> MUST OFTEN COMPARE APPLES AND
> ORANGES.

Chapter 1: The PROBLEM of COMMENSURATION

Commensuration is the process of measuring, in terms of a common unit, properties that are ordinarily measured in terms of different units. Examples of such properties are impacts on economic, environmental, and social dimensions, as represented, for example, in the National Development (NED), Environmental Quality (EQ), Regional Development (RD), and Social Well-Being (SWB) accounts of the Water Resources Council's *Principles & Standards for Planning Water and Related Land Resources* (1973). Other examples are impacts on different segments of the public. Commensuration is virtually always required for rational planning.

Rational Planning

"Rationality" has been defined as "Justifiability of values, beliefs, and/or behavior in terms of the principles of inductive and deductive reasoning" (Anderson, Deane, Hammond, McClelland, & Shanteau, 1981, p. 199). Applied to planning, this means (a) that selection of a plan must be justified in terms of relevant fact judgments about the likely consequences of each alternative plan and value judgments about the desirability of each consequence and (b) that these fact and value judgments, in turn, must be justified in terms of the principles of scientific method. The importance of applying scientific method to value judgments is not nearly so widely appreciated as the importance of applying it to fact judgments. One purpose of this paper is to show why it is important to be scientific about the measurement of values and how one can do so.

Note, incidentally, that the definition of rationality given above allows room for reasonable people to differ. It requires only that actions be consistent with beliefs and values; because it does not require that reasoning be based on the same assumptions or values, it does not require agreement as to conclusions.

The Need for Commensuration

Commensuration is important in water resources planning, and in planning decisions generally, because of the complex nature of the impacts of alternative plans. Virtually any plan or policy alternative will have many kinds of impacts, some desired and some not. Because planning decisions have many kinds of impacts, they are what are called *multiattribute* decisions. The general structure of a multiattribute decision problem is represented diagramatically in Figure 1.1.

The square on the left is a "choice point", that is, a point at which a decision needs to be made. The three lines radiating from it represent alternative courses of action, A, B, and C. For example, the first alternative might be to construct an earth-filled dam at a particular location. Each course of action terminates in a row of squares, which represents its anticipated impact, each square in the row representing the measure of that impact on a different dimension. For example, the dam might have impacts on irrigation water, recreation, and environmental quality. The impacts of the alternatives are thus conceived as multidimensional.

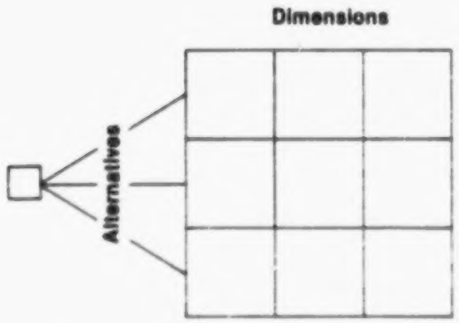


Figure 1.1. The Structure of Multiattribute Decision Problems

Federal laws and regulations governing water resources planning clearly recognize the multiattribute nature of water planning decisions. The *Principles & Standards* (1973) establishes a system of four accounts (NED, EQ, RD, and SWB) and specifies (p. 14) that the selection of a recommended plan from among the alternative plans be "based upon an evaluation of the tradeoffs between the objectives of national economic development and environmental quality and considering, where appropriate, the effects of the plans on regional development and social well-being." The *National Environmental Policy Act (NEPA)*(Sec. 102(2)(B)) requires all agencies of the Federal Government to identify and develop methods and procedures "which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations...."

Measuring economic, environmental, and social impacts on separate scales (e.g., in terms of dollars, habitat units, arrests, etc.), while necessary, is not sufficient for planning decisions. What is usually required in a planning decision, or in any other multiattribute decision, is a choice between an alternative that is superior in some respects, say, economic, and an alternative that is superior in others, say, environmental. Seldom do all differences favor the same alternative. In order to decide whether the economic differences in favor of the first alternative are greater or less than the environmental differences in favor of the second, these differences must be compared; and, for comparison to be possible, the differences to be compared must be evaluated, explicitly or implicitly, on a common scale. Whether it is performed intuitively or analytically, commensuration is required for virtually all planning decisions.

Current Practice

The prevalent practice in planning is to stop short of addressing the problem of commensuration and to leave this problem entirely to the decision maker. One common practice is simply to present projections of impacts on whatever dimensions seem most appropriate, as in the table below:

Table 1.1: Impacts

	Income	Population	Percent Middle Class
Baseline	$83,779	2,288	36
Plan I	$114,460	2,545	36
Plan II	$72,463	5,076	54

No attempt is made to help the decision maker with the task of commensurating over the diverse dimensions of income, population, and size of middle class in order to reach an overall evaluation of each plan.

A more advanced practice (e.g., Fitzsimmons, Stuart, & Wolff, 1975) is to make subjective evaluations of objective impacts by assigning plusses, zeros, and minuses to the various levels of impact, in comparison with Baseline, according to some scale like the following:

very positive	++
positive	+
neutral	0
negative	-
very negative	--

These values might be presented in a table like the one below:

Table 1.2: Evaluation of Impacts,
Not Commensurated

	Income	Population	Size of Middle Class
Plan I	+	+	0
Plan II	-	-	+

This may give the decision maker some help in evaluating the impacts, depending on the source and validity of the value judgments; but, because each dimension is evaluated on its own terms, the problem of commensuration across dimensions is not addressed. In general, current methods present the information that must be commensurated but tend to provide little or no help with the commensuration process, itself.

The Importance of Judgment and Decision Aids

In complex planning decisions, many more factors must be taken into account than can be grasped by the unaided human intellect. More technical judgments must be made than can be responsibly made by any one person, and more value judgments (for example, judgments about the relative worth of environmental and economic impacts) must be made than can be made by any one person at one time. The number of items of information that the human mind can process at one time is severely limited (Miller, 1956; Broadbent, 1975). As a consequence, information processing becomes less efficient as the number of dimensions increases (Attneave, 1959, p. 74; Einhorn, 1971); people tend to take into account only a few dimensions when evaluating mutlidimensional stimuli, such as impacts of alternative plans (Shepard, 1964; Slovic & Lichtenstein, 1971). This is true even of experts making judgments in their areas of expertise (Goldberg, 1965; 1970; Slovic, Fleissner, & Bauman, 1972). The danger, of course, is that the dimensions not taken into account by the decision makers will be important to significant segments of the affected population.

The way to do justice to problems of the complexity of public planning decisions is to break them down into problems small enough to be grasped in their entirety, to solve the smaller problems, and then to combine the solutions to the smaller problems into a solution to the overall problem, a general strategy known as decomposition (see Polya, 1957; Wicklegren, 1974). The idea is to "divide and conquer".

The best way to put together an overall solution from the part solutions is to express the solutions to the smaller problems as numbers and then to combine the numbers arithmetically. This procedure ensures that all of the quantified values will influence the final decision and, moreover, that they will do so in proportion to their importance. *The great merit of quantification is that it permits simplification without loss of information.* (Of course, for this procedure to be useful, the numbers must be used in a way that retains their meaning. How to do this will be discussed later.)

Market-Based vs. Judgment-Based Methods for Commensuration

There are two broad classes of methods for quantifying the public's relative preferences for various goals: market-based methods (which provide the sole basis for most cost-benefit analyses) and judgment-based methods. While both seek to quantify diverse impacts in terms of a common scale, they differ in their approaches to arriving at such a scale (Lord, Deane, & Waterstone, 1979).

Market-based methods seek to measure the values of diverse things in terms of the amounts of money people are willing to pay for them on the market. Thus, the value of an increase in water available for irrigation might be measured in terms of the market value of its consequences, such as increases in the harvests of crops. Similarly, the value of a certain habitat might be measured in terms of the amounts people are willing to pay for recreation or real estate in such areas.

Judgment-based methods seek to measure the values of diverse entities simply by asking people to judge their worth on a common scale. Thus, the relative value of an increase in irrigation water and a loss in habitat quality might be obtained by asking representatives of the public how much of an increase in acre-feet of available irrigation water it would take to provide a positive value that would offset the negative value of the loss of a given habitat.

(*Technical Note*: The defining characteristic of market-based methods, as that term is used here, is the analysis of decisions made in naturally occurring situations, and the defining characteristic of judgment-based methods is the analysis of decisions made in contrived situations. It is because the former are almost always economic decisions that the name "market-based" is used. It should be noted, however, that such analyses have also been carried out on political decisions, where votes constitute the "currency".)

The market-based methods are less costly than the judgment-based methods, for price data are less expensive to obtain than judgment data. Advantages, however, are divided, market-based methods having the advantage of truth to life and judgment-based methods having the advantage of analytic control. These benefits are discussed below.

Truth to life. Market-based methods are based on binding, real-life decisions. Consequently, they would be expected to predict well how people will feel and act in similar real-life situations. Judgment-based methods, on the other hand, are based on hypothetical decisions. They ask a person how he/she *would* respond in such-and-such a situation. One danger with judgment-based methods is that people may not feel the same way about hypothetical situations as they feel about real situations. Another is that, even if they feel the same way, they may not be motivated to express their feelings honestly. Instead of responding in a straightforward way to the hypothetical consequences posed by the analyst, they may exaggerate or minimize their feelings in order to influence the very real consequences of the analysis itself, a practice known as "gaming". (See Webb, Campbell, Schwartz, & Sechrest, 1966).

Analytic control. Judgment-based methods permit one to manipulate the properties of the object or event being evaluated, to exercise analytic control. This advantage expresses itself in a number of ways:

a. generality of application,
b. clarity of causal interpretation,
c. accuracy of information,
d. value clarification, and
e. flexibility in weighting publics.

Each of these ways will be discussed in turn.

(a) Judgment-based methods are quite general in their application for the simple reason that hypothetical situations ("hypothetical markets") can be created for evaluating virtually any dimension. By contrast, markets and prices exist for only a restricted class of things (Haimes & Hall, 1974; Sinden & Worrell, 1979; Stokey & Zeckhauser, 1978, pp. 297-308). While it may not be quite true that "the best things in life are free", certainly many things of value are not bought and sold in any market. Public goods, such as beautiful scenery and clean air are generally beyond the reach of market-based techniques. Many environmental and social dimensions fall in this category.

It is essential that means be provided for quantifying dimensions, such as environmental and social, that are inherently difficult to quantify. Otherwise, analyses will tend to gravitate toward "hard" dimensions, with the result that undue emphasis will be placed on engineering and economic considerations. Indeed, it would seem to be the restricted generality of market-based methods that motivated the clause in the *NEPA Final Regulations* (Sec. 1502.23) that reads: "For purposes of complying with the Act, the weighing of the merits and drawbacks of the various alternatives need not be displayed in a monetary cost-benefit analysis and should not be when there are important qualitative considerations." When considerations are present to which market-based methods are not applicable, some method must be used that is applicable to all considerations.

(b) A second advantage of the greater analytic control possible with judgment-based methods is the greater clarity with which they identify the factors that influence the decision. An item that is purchased on the market could have been purchased for any of a variety of reasons. Residential property values farther from an airport may be higher in part because of the greater distance from the airport, but other factors may also be involved, factors which may have been operative before the airport was even built. How much of the difference in price is attributable to distance from the airport and how much to other factors can not be determined with any great assurance using the indirect methods of control to which market-based methods are restricted. (*It is important to note that this limits the truth-to-life value of the market-based methods, since binding, real-life decisions will predict future real-life decisions only in situations that are alike with respect to those variables that are, indeed, causal.*) Judgment-based methods, on the other hand, can employ direct methods of analytic control, asking for judgments along just the one variable of interest or presenting items for judgment that differ with respect to just this one variable. Direct control enables the analyst to determine with much greater assurance what the factors are that influence preferences.•

(c) Greater analytic control permits greater accuracy in measuring preferences. Using hypothetical situations, it is a simple matter to vary, say, the price of water, asking people whether they would be willing to pay $1 for 1000 gallons, $10 for 1000 gallons, and so forth, and thus to determine the point at which they would begin to look for other means to obtain water. If water sells for 70 cents/1000 gallons, however, the most that can be inferred from this is that water is *at least* this valuable. In general, market-based methods tend to give minimum estimates of worth. When the product is worth more than the price, the difference between the amount consumers are paying and the maximum amount they would be willing to pay is referred to as "consumers' surplus". To measure worth adequately, market analyses must take account of consumers' surplus. Analysis of the extent to which demand does or does not vary as a function of price (demand elasticity) does not provide an entirely satisfactory approach to this problem (see Stokey & Zeckhauser, 1978, PP. 149-151).

Judgment-based methods achieve greater accuracy in another respect. Dollars do not reflect values in any simple way. $10,000 is not twice as valuable as $5000. As a general rule, the first $5000 is of greater value than the second. This is why $5000 would be valued more by a poor person than by a wealthy one. (Most market-based analyses, however, assume that a dollar is of equal value to both the rich and the poor.) The greater control possible in hypothetical situations permits changes at different points along a dimension to be compared with one another in order to obtain more precise information about their relative worths.

The greater control possible in hypothetical situations also permits the use of a variety of techniques for assessing values. For example, *direct methods* ask people for judgments on verbal, numerical, or graphic rating scales. *Indirect methods* simply ask for choices, and then use these to infer preferences. Because different methods are likely to lead to different kinds of error, it is desirable to use more than one method so that the errors may have some chance of cancelling one another out, a technique knows as *triangulation*.

(d) The greater control possible in hypothetical situations over the information on which the value judgments are based and over the manner in which these judgments are made also makes possible a very desirable process known as *value clarification*. By ensuring that the respondents are aware of all realistic alternatives, by presenting complex problems in small enough pieces that they can base their choices on all the relevant factors, and by ensuring that they are aware of the implications that various judgments have for one another, the analyst can help the respondents to make wiser choices, choices that are more nearly in their own best interests than those they might have made in the market. Value clarification should thus contribute to better planning decisions.

(e) Finally, judgment-based methods permit greater control over the process by which the preferences of different individuals are combined into an overall evaluation of each alternative. Market-based methods weight individuals in proportion to their participation in the market, that is, roughly in proportion to their wealth. In comparing the relative values of a portion of a stream used (by people of modest income, at no cost) for tubing and a portion used (by people of higher income, at some cost) for fly fishing, market based methods would tend automatically to indicate a higher value for fly fishing. Judgment-based methods, on the other hand, obtain judgments from representatives of identifiable publics, and these publics can then be weighted according to whatever principle (e.g., one-man-one-vote) seems to be most fair.

In comparing market-based and judgment-based methods, the balance would seem to be in favor of judgment-based methods. Indeed, one factor seems capable of carrying the argument by itself: Federal water resources planning virtually always involves some considerations, particularly in the EQ and SWB accounts, that can be evaluated in a straightforward manner *only* by judgment-based methods. The method developed in this paper, and the one that is recommended, is therefore judgment-based.

A number of excellent reviews of judgment-based techniques for commensuration are available (Bishop & McKee, 1976; Cohon & Marks, 1975; Fischer, 1975; Fishburn, 1967, 1968; Hobbes, 1979; Huber, 1974b; Lord, Deane, & Waterstone, 1979; MacCrimmon, 1973; Mumpower, Stewart, et al., 1979; Seaver, 1976; von Winterfeldt & Fischer, 1975). The purpose of this paper is, not to produce another review, but (a) to select from the many techniques available techniques suitable for commensuration in Federal water resources planning, (b) to organize these into an overall plan for commensuration, and (c) to describe the resulting method in sufficient detail that its logic and application will be clear to potential users.

The fact that the recommended method is judgment-based should not be taken to imply that it is based on the assumption that judgment-based methods should be used to the exclusion of market-based methods. Market-based and judgment-based methods operate from different assumptions and have strengths and weaknesses that tend to be complementary. They are best used, where possible, as complementary operations for converging on common truths. For example, if a judgment-based method yields a lower equivalent monetary value than people are actually paying or will be paying, the results of the judgment-based method should be reexamined. People should be willing (other things being equal) to pay out at least as much to preserve agricultural land as they would have to pay out in additional food costs if the land were to be converted to some other use.

The recommended method distinguishes between commensuration within publics and commensuration across publics, two steps in a "cascade" of tradeoffs, and presents techniques for both tasks. While the techniques presented for these two tasks are both judgment-based, their roles vis-a-vis market-based methods are quite different. The techniques for commensurating within publics are alternatives to market-based methods. For commensurating within publics, one can use either judgment-based methods or market-based methods (or, preferably, a combination of the two). For commensurating across publics, however, there seems to be no alternative to human judgment. The judgment-based techniques for commensurating across publics are therefore recommended for all cases, irrespective of whether the preceding analysis is judgment-based or market-based.

Because the recommended method is judgment-based, care will be taken, in presenting the method, (a) to show how to make full use of its capacity for analytic control, (b) to suggest ways to make hypothetical situations it employs as true to life as possible, and (c) to show how to keep the costs of obtaining judgment data to a minimum.

The Recommended Method

The recommended method for commensuration on the basis of public value judgments involves a number of steps. These are:

1. Identifying the affected publics,
2. Identifying the issues,
3. Measuring scale values,
4. Measuring weights,
5. Performing dominance analyses,
6. Commensurating within publics,
7. Commensurating across publics, and
8. Evaluating equity and risk.

These can be grouped into three broad phases: structuring the problem, gathering information, and making a choice. The recommended method provides for all three.

Steps 1 and 2, identifying the impacted publics and identifying the issues, are problem-structuring steps. In the Bureau of Reclamation's Coal Creek Project, which provided a field test of the Cascaded Tradeoffs Method, six publics were identified, the four communities that would be served by the project and the two neighboring communities, and six dimensions of potential impact were identified: municipal and industrial water supply, population, fish and wildlife, recreation, conversion of agricultural land, and dam safety. Steps 1 and 2 are dealt with primarily in Chapters 2 and 3.

Steps 3 and 4, measuring scale values and measuring weights, are information-gathering steps. In the Coal Creek Project, these steps established, for example, what the optimal population level was judged to be by each public and how important population changes were judged to be in relation to changes on the other dimensions. Steps 3 and 4 are dealt with in Chapters 4 and 5.

Steps 5, 6, 7, and 8 are decision-making steps. In the Coal Creek Project, two decision-making steps were involved. First, it was possible to reject the No Project alternative without the need for commensuration, since no public preferred it to the Coal Creek alternative. Second, because the Coal Creek alternative was preferred by some publics and the Crescent alternative by others, it was necessary to commensurate the value judgments of the different publics onto a common scale before a choice could be made between these two alternatives. Steps 5, 6, 7, and 8 are discussed in Chapters 6 and 7.

The Frontispiece presents a flow diagram of the key steps in the recommended method.

The *Principles & Standards* (1973, p. 107) states that "selection of a recommended plan will be based upon an appraisal so that the beneficial and adverse effects to the mix of objectives, to the best of current understanding and knowledge, reflect the priorities and preferences expressed by the public at all levels to be affected by the plan." The recommended method enables the public to express its priorities and preferences in a manner that permits (a) determination of a reasonable, defensible measure of overall social value and (b) application of this measure to a variety of alternative plans, with or without mitigation measures and with or without uncertain futures.

This is about as far as an analysis of public values can go. Commensuration of the other factors relevant to a choice among plans (e.g., the values of the rest of the nation) will require value judgments from the decision maker. The best way to obtain and aggregate such judgments would be by means of an extension of the recommended techniques.

Features of the Recommended Method

The recommended method possesses a number of desirable features in addition to those associated with the general class of judgment-based methods. These are decision aiding, fact-value separation, de-biasing, full commensuration (both within and across publics), adaptability to both low- and high-budget projects, attention to the need for creative thinking about problem structuring as well as critical thinking in alternative selection, and recognition of the role of intuitive processes in decision making.

Decision aiding. Because there is ordinarily no single decision maker for public planning decisions and because the various decision makers will usually differ in their assumptions and values (Allison, 1971; Peterson & Gemmell, 1977), it is seldom appropriate for a planner to recommend a course of action unconditionally. Rather, a planner should identify and structure correctly the important aspects of the decision problem, so that each decision maker will be better able to see the implications of his/her assumptions and values for a choice among alternatives. The analysis should also be presented with sufficient clarity that the decision maker has a reasonable basis for accepting or rejecting each major step. Thus, a method for commensuration will not make decisions, but will prepare and present information in a way that can help a variety of persons to perform their roles in the decision-making process in an intelligent, informed manner. (The term "decision maker" often appears in the singular in this paper. When it does, it will be intended as referring collectively to the many decision makers who are always involved in any planning decision.)

Fact-value separation. Frequently, the public is asked to evaluate alternatives whose consequences they understand only poorly, and, frequently, they choose alternatives that lead to consequences they do not themselves desire. Fact-value separation (Rawls, 1971; Hammond & Adelman, 1976) refers to the division of the overall task of evaluating alternatives into two subtasks: (a) estimating the likelihood of various possible outcomes for each alternative (fact judgment), and (b) evaluating the desirability of those outcomes (value judgment). The recommended method achieves fact-value separation.

The distinction between facts and values, like the distinction between night and day, is not a sharp one at the boundary. It is not always clear whether a given statement is a statement of fact or a statement of value. Nevertheless, like that between night and day, that between facts and values is a useful one. There are two reasons for separating fact judgment from value judgment in planning. One has to do with obtaining uncontaminated judgments of facts and values. The other has to do with the selection of appropriate means for resolving different kinds of conflict.

If fact judgments are not separated from value judgments, experts who prefer a certain outcome (e.g., construction of a project) are likely to select facts to support their preference, and representatives of the public who believe (correctly or incorrectly) that a particular plan will or will not get them what they want are likely to distort their value judgments to support their beliefs. Though such distortions may result from deliberate attempts to manipulate the outcome of the analysis, to "game", they need not be. Sincere judgments can be distorted in this fashion as a consequence of the limited human capacity for processing information and the need to maintain consistency of beliefs and values (DeSoto, 1960, 1961; Festinger, 1957; Lecky, 1945).

The best way to keep fact judgments from being distorted by values and value judgments from being distorted by beliefs is to obtain fact and value judgments separately. Ideally, fact judgments and value judgments should be made by different people. Fact judgments about the consequences that are likely to result from each alternative plan should be made by technical experts (though their reasoning should be open for public review), and value judgments about the desirability of these consequences should be made by representatives of the public. In addition, fact judgments should be made in ignorance of the associated values, and value judgments should be made in ignorance of the associated facts: When experts make their projections of various possible impacts, they should do so knowing as little as possible about the values of the various publics regarding these outcomes. And, when representatives of the various publics evaluate outcomes, they should do so knowing as little as possible about which plans are associated with which outcomes.

The second reason for distinguishing between fact judgment and value judgment is that obtaining separate fact judgments and value judgments can help determine whether conflict among publics is essentially fact conflict, value conflict, or interest conflict. Fact conflict would be illustrated by the case of a public that believes that one project would provide more water and a public that believes that a different project would provide more water. Value conflict would be illustrated by the case of a public that prefers a project that will provide more water (though it would also harm the environment more) and a public that prefers a project that would harm the environment less (though it would also provide less water). Interest conflict would be illustrated by the case of a public that prefers a project that will harm their environment less and another public that prefers a project that will harm *their* environment less. Different techniques are appropriate for dealing with these different kinds of conflict (Lord, et al., 1979). The scientific method, nominal group techniques (Linstone & Turoff, 1975), and educational programs are appropriate for dealing with fact conflict. The analytic techniques presented in this paper can reduce value conflict. And techniques that rely more heavily on motivational and group processes (Creighton, 1980) can reduce interest conflict.

De-biasing. A large number of influences tend to bias human judgments. The most important of these are identified in the pages to follow, and techniques for correcting for them are designed into the judgment procedures.

Full commensuration. In public planning decisions, the situation is actually more complex than in the kind of multiattribute decision problem represented in Figure 1.1. Not only must multiple dimensions be evaluated in public planning decisions, but these dimensions must ordinarily be evaluated by different publics. The general structure of multiattribute decision problems in the context of public planning decisions is depicted in Figure 1.2. This figure differs from Figure 1.1 in the addition of a dimension for publics. Each alternative in a public planning decision is thus seen as having a potentially different multidimensional impact on each of a number of publics.

Commensuration does not occur at a single point in planning.

Commensuration must be accomplished both across dimensions within publics and across publics, and it should reflect both the judgment of respresentatives of the various publics and the judgment of various decision makers.

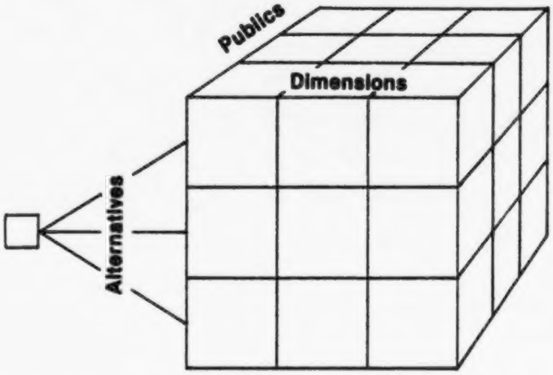


Figure 1.2. The Structure of Multiattribute Decision Problems in the Context of Public Planning Decisions

The recommended method treats commensuration within publics and commensuration across publics differently, in a two-step "cascade". Commensuration within publics is the less problematic step, and it is accomplished by the straightforward application of widely accepted analytic techniques for multiattribute decision making. Commensuration across publics is more problematic, for reasons that will be dutailed later. (See especially pp. XXff.) While the same analytic techniques employed for commensurating within publics are employed for commensurating across publics, they are used here more as judgment and decision aids, and more of the final responsibility for this step in the commensuration process is left to the various decision makers.

The judgment and decision aids for commensurating across publics aid the judgment process in two ways. They simplify the judgmental task by focusing attention on value judgments and, in particular, on a small number of critical value judgments. And they make the judgmental task more meaningful by relating what is being judged to the decision maker's experience.

Adaptability. The recommended method can be adapted to both low- and high-budget projects. It provides two techniques for measuring scale values and two techniques for measuring importance weights. It also offers two techniques for sampling representatives from the impacted publics. By selecting from these alternatives, the planner can tailor the proposed method to a variety of problems and budgets.

Creative thinking and problem structuring. Structuring the problem is generally considered to be the most important phase in problem solving. If an important dimension is overlooked (as is often the case with social and environmental dimensions), if an important alternative course of action is not considered (as is often the case with non-structural alternatives), or if an important possible consequence is not thought of (as is often the case with certain kinds of legal and extralegal action), all the best efforts in the information-gathering and decision-making phases may fail to produce a good decision.

As important as the problem structuring phase is, it is seldom given more than passing mention. The probable reason for this is that problem structuring is in large part a creative thinking task, and most approaches are oriented toward critical thinking tasks. The proposed method addresses both creative and critical thinking tasks.

Creative thinking tasks, as has been suggested, involve the generation of ideas. In the context of planning, this means the generation of plans, outcomes, publics, and dimensions of value. Critical thinking tasks, on the other hand, involve the evaluation of ideas for reasonableness with respect to assumptions and/or data. In the context of planning, this means the reasonableness of the evaluation of plans with respect to the various fact judgments and value judgments on which this evaluation is based. While the problem-structuring phase is largely a creative thinking task, the phases of gathering information and making the choice are largely critical thinking tasks. The overall task of commensuration thus requires both creative and critical thinking.

Different techniques (and even different attitudes) are appropriate for creative and critical thinking. Techniques for critical thinking are the most highly developed and the best known. Yet explicit, teachable techniques are also available for creative thinking (Gordon, 1961, 1971; McKim, 1972; Osborn, 1963; Stein, 1974, 1975; Zwicky, 1957, 1969). Each will be described where appropriate. An attempt will be made to treat both aspects of the overall task of commensuration in as balanced a manner as the availability of techniques permits.

Intuitive and analytic processes. The distinction between intuitive and analytic thinking is a distinction between psychological processes, not tasks. One can think intuitively about creative or critical thinking tasks, and one can think analytically about creative or critical thinking tasks. Intuitive thinking deals with wholes, in an associative or metaphorical fashion. Analytic thinking breaks wholes into parts and recombines the parts, according to logical or mathematical rules.

Methods for decision making generally deal exclusively with analytic techniques. The present treatment will depart from this practice only in calling attention to the cooperative relationship between intuitive and analytic processes. The reason intuitive processes are not even mentioned in most treatments, and will be discussed only briefly in the present one, is that intuition is acquired more from experience than from formal teaching. While this paper can not teach intuition, however, it can at least call attention to it and suggest how it can be used.

The proper role of intuition is as a guide to analytic processes and a check on their results. To apply analytic techniques without the "understanding", "insight", or "vision" of intuition is to apply them in a blind, cookbook fashion. The results can be bizarre and even dangerous.

Yet intuition should be no more than a guide, for to rely on intuition alone, without the disciplined check of analytic processes, can be to rely on opinions, prejudice, and mental short-cuts. This, too, can be dangerous. Because intuitive and analytic processes are subject to different kinds of error, each can provide a check on the other.

To apply intuitive processes to the problem of commensuration, one can (a) ask frequently, "Does this make sense?" "Does it seem right?" and (b) think about the problem in terms of concrete situations and real people. If the results of the analytic computations seem reasonable, if they indicate what was pretty well known already, then they have passed the test of intuition. However, if the results of the computations do not "make sense", then either the numbers are in error, or intuition needs reeducating, or both.

Usually, the way in which intuition needs reeducating is in being brought to an appreciation of the implications of the solutions to various subproblems for the solution to the overall problem. Calculation does what intuition, with its limited processing capacity, can not readily do, combine large amounts of information. If the calculations do not make sense immediately, the analyst can usually come to see that they do by going over them and thinking about them.

Nevertheless, it may be that the numbers are in error, and they should be checked. The arithmetic must be checked, of course, but another likely place for error is in the numbers that the arithmetic is performed on. Various sources of such errors and ways for dealing with them will be discussed later. These include errors in creative thinking (perhaps some factor was overlooked or misconstrued in the problem structuring phase), as well as in critical thinking.

One final caution: It is recommended that initial attempts to apply the techniques to be described be made in consultation with someone experienced in the use of such techniques. An intuitive understanding of method is as important as an intuitive understanding of content.

Chapter 2: IDENTIFYING the IMPACTED PUBLICS

Because commensuration in public planning is properly based on the values of the potentially affected publics, identifying these publics is an essential part of the commensuration process in Federal water resources planning. The relationship of the task of identifying the affected publics to the overall structure of public policy decisions is shown in Figure 2.1:

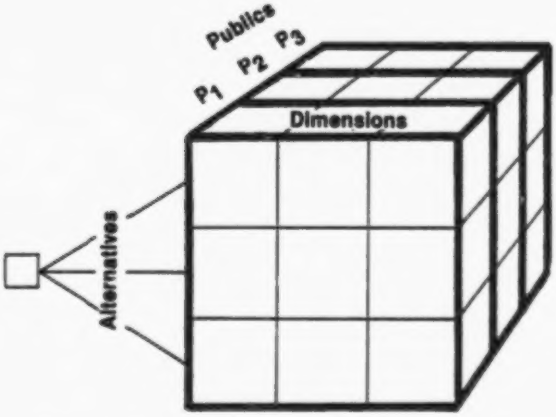


Figure 2.1. Identification of Publics

This figure is intended simply to highlight those aspects of Figure 1.2 to which this chapter is relevant. Similar figures will introduce subsequent chapters and sections to help the reader maintain an overview of the entire process.

The *Principles & Standards* (1973, p. 107) requires selection of a recommended plan to be "based upon an appraisal so that the beneficial and adverse effects to the mix of objectives, to the best of current understanding and knowledge, reflect the priorities and preferences expressed by the public at all levels to be affected by the plan." Before the public's priorities and preferences can be assessed, the affected publics must, of course, be identified and contacted. This process should be initiated early, in the scoping phase, before the set of alternative plans has been decided upon. The *Principles & Standards* (1973, p. 96) emphasizes the importance of "soliciting public opinion early in the planning process."

It is a common practice for agency personnel to make value judgments on behalf of the public. Time and other restrictions may sometimes leave no choice in this regard. In such cases, agency personnel should first talk as extensively as possible with representatives of the affected publics and then use one of the methods to be described for making their judgments explicit. It is far more consistent with the *Principles & Standards*, however, to obtain judgments directly from representatives of the publics, and this, of course, is the recommended practice.

Kinds of Publics

It is useful to distinguish between two kinds of publics: (a) publics to be contacted for ideas relevant to problem structuring (see Steps 1 and 2, p. 9), and (b) publics to be contacted for value judgments (see Steps 3 and 4, p. 9). While *problem-structuring publics* should simply represent all points of view, *value-judgment publics* should represent the various points of view in proportion to their frequency and intensity. Problem structuring is a qualitative process; value judgment, a quantitative one.

Problem-structuring publics should include as great a range of special interest groups and of persons holding extreme views as possible: farmers, environmentalists, businessmen, Indians, and so forth. The *Principles & Standards* (1973, p. 96) specifies that "A broad spectrum of public groups and interests must be considered and consulted in the identification of the components." The greater the diversity of views sampled during the problem-structuring phase, the greater the likelihood that all relevant publics and issues will be identified and that all relevant considerations will be incorporated into the framing of the questions to be presented for eliciting value judgments.

Value-judgment publics, on the other hand, should be publics from which it is possible to sample persons who can, collectively, be regarded as legitimate representatives of the entire affected population. This means two things. First, the set of value-judgment publics must be properly structured. It must, as will be discussed later, be complete, economical, nonredundant, and relevant. Second, individuals must be sampled from these publics in a manner that assures their legitimacy as representatives.

The next section deals with the identification of publics, for both problem-structuring and value-judgment purposes. The last two sections deal with the structuring of publics and sampling from publics.

Identifying the Publics

Identifying the publics is a creative thinking task. The initial goal should be to generate a list of publics that is as long as possible. No potential public should be excluded, even if inclusion seems inappropriate at the time. The identification of publics is an important part of any public involvement program (e.g., Creighton, 1980).

There are a number of methods for identifying publics. These methods also serve to sample representatives from publics for purposes of problem structuring. Publics can be identified, and representatives selected for problem structuring, on any or all of the following bases:

a. election or appointment to public office;

b. identification by agency personnel, knowledgeable locals, or public involvement groups;

c. self-identification (e.g., by attendence at public meetings or by writing to newspapers, political representatives, or the agency); and

d. identification by means of the "snowballing" technique, starting with persons identified by any of the other methods on this list, asking them to nominate other persons, asking these persons to nominate still others, and so forth.

Identification by knowledgeable locals can be accomplished by beginning with local planners, government officials, and heads of organiziations. Various governmental agencies (e.g., the Fish and Wildlife Service, the Environmental Protection Agency) appoint people to review each project. These people should also be contacted.

Identification by agency personnel can be based on an analysis of associations, a geographic analysis, a demographic analysis, an historical analysis, or field interviews (Willeke, 1977). Analysis of associations is a process of consulting available lists (e.g., the yellow pages, chamber of commerce lists, newspaper lists, city and county directories) of organized groups and picking out those that appear to have a possible interest in being involved. Geographic analysis involves the study of maps and photographs to determine areas (e.g., a flood plain, the area that would be inundated by a proposed reservoir, the area downstream from a proposed sewage treatment plant) that should be singled out for special attention. Demographic analysis is based on such identifying attributes as age, sex, race, education, income, and occupation that are easily measured and commonly a matter of public record. Historical analysis is based on a content analysis of newspaper articles, reports, brochures, etc. Comparative analysis refers to examining lists of the affected publics identified in similar projects. Finally, the use of field interviews for identifying publics and their representatives would usually involve the snowball technique. (For excellent discussions, see Creighton, 1980; Willeke, 1977.)

It is desirable to use multiple methods in identifying publics in order to correct for the errors inherent in each of the individual methods. For example, representatives who are self-identified tend to be well-to-do persons who have been successful in their attempts to influence governmental decisions and persons who have strong opinions. And elected and appointed representatives tend to have values that differ in a number of ways from those of the publics they represent. (See Campbell, Converse, Miller, & Stokes, 1964, pp. 83, 114-117, 121-122).

Though the relevant publics will ordinarily differ from study to study, two publics are of sufficiently general importance to deserve special mention: the rest of the country and future generations. The principal impact on the rest of the country stems from the fact that most projects are financed in part from general tax revenues. While the publics to whom the benefits accrue are routinely given careful attention in water planning decisions, the much larger public that shares the costs tends to be given less consideration.

Nevertheless, the position taken here is that, because the impacts on the rest of the country are so highly diffused, the omission of them from the commensuration analysis, at least, is not a serious one. (See Stokey & Zeckhauser, 1978, p. 252, for a related view.) An analysis has to stop somewhere. There would seem to be sufficient opportunity to take account of the values of the rest of the country in the budget allocation process, the cost-benefit screening of candidate plans, and the review of plans by other Federal agencies. (See Lord, 1980, for a similar view.)

Impacts on future generations, however, particularly those in the area of the project, could be quite pronounced. Indeed, such impacts, either beneficial or detrimental, could be the most important impacts of a project. The *Principles & Standards* (1973, p. 11) specifies that "Appropriate consideration will be given to long-term environmental and social well-being effects which may extend beyond periods significant for analysis of national economic development or regional development beneficial and adverse effects." If it can be assumed, as a first approximation, at least, that future publics will evaluate impacts in much the same way as current publics, the values of the current publics can be assessed for scenarios involving future generations. Any systematic biases could then be corrected for by adjusting this first approximation in the direction in which values might be expected to change in the future.

Structuring the Publics

The set of publics to be contacted for value judgments must be properly structured and carefully sampled. Otherwise, no amount of care in obtaining the value judgments will be able to assure that these judgments will fairly represent the values of the affected population. Structuring the set of publics is a critical thinking task. It involves rejection of those structures that are not consistent with the following requirements:

Completeness,
Economy
Nonredundancy, and
Relevance.

Completeness requires that no significantly affected public be excluded. It is the only one of these requirements that is also important for problem-structuring publics. *Economy* requires that no public that is not significantly affected be included. *Nonredundancy* requires that no person be counted in more than one public. Relevance requires that the division of the population into publics be such that those who would feel substantially differently about the impacts of the alternatives are in different publics and that those who would feel much the same about the impacts of the alternatives are in the same publics.

Ideally, the set of publics contacted for value judgments will constitute a *partition* of the entire affected population. A partition is a division into parts in which every member of the whole is included in one and only one part. Partitioning the population is like cutting up a pie, since every part of a pie is included in one and only one piece. A partition thus satisfies both completeness (everyone is counted at least once) and nonredundancy (no one is counted more than once).

There are a number of bases of classification that guarantee a partition. Classification on the basis of income is one, since everyone has some level of income (even if it is $0), and no one has more than one level of income. Another is classification on the basis of age, since everyone has one and only one age. Other bases of classification, while not guaranteeing partitions, can be expected to produce acceptably good approximations to ones. Classification on the basis of occupational category (e.g., farmers, business people, etc.) or place of residence (e.g., in flood plain, out of flood plain) are examples. Everyone has an occupation, even if it is unemployed or retired, and a place of residence, and the number of people who have two occupations or two places of residence is, as a rule, negligible.

Relevance is the requirement that the basis of classification divide the population into publics that would feel differently [illegible] the impacts of the alternatives. If representatives are [illegible] be selected from the publics by random sampling, any relevant partition can be appropriate. If sampling is to be of elected representatives, however, the number of acceptable relevant partitions is severely restricted, for the partition must then divide the population into publics that, in fact, have elected representatives. The most likely possibilities are cities, counties, tribes, or electoral units within any of these.

Partitioning the population into political units has the additional advantage that it is easy to obtain a good estimate from the census of the size of such publics. Partitioning along political lines should be employed, however, only when such a partition is relevant, that is, when it divides the population into publics that would feel differently about the impacts of the alternatives. The division into upstream communities and downstream communities, in-basin communities and out-of-basin communities, Indian communities and non-Indian communities might often be relevant. However, if the major interest groups are, for example, developers and enviromentalists and each community contains substantial numbers of both, division along community lines will not be relevant. Such a division would obscure major differences, leaving commensuration across the important interest groups to the intuitive judgment of the representatives rather than dealing with it explicitly.

When random sampling is used, another way to structure the publics is to sample from a single, undifferentiated public and then to partition the sample on the basis of a cluster analysis (Anderberg, 1973; Gum, Roefs, & Kimball, 1976). An advantage of cluster analysis is that it groups people on the basis of their expressed values, rather than on the basis of predictors of their values. The cluster analysis should be based specifically on evaluation of the impacts of the alternatives, however, not on overall value structure. A properly performed cluster analysis should ensure that the affected population is partitioned and that the partition is relevant.

Sampling from the Publics

There are two general methods for sampling: *key-informant sampling* and *random sampling*. While random sampling is the method that is more frequently used in scientific research, key-informant sampling is the method that is more frequently used in public planning. Random sampling and key-informant sampling achieve different, though potentially complementary purposes. Random sampling obtains a sample that is statistically representative, or typical, of the affected population. Key-informant sampling obtains a sample that is intentionally atypical: atypically diverse in the case of sampling from problem-structuring publics and atypically "legitimate" in the case of sampling from value-judgment publics.

Key-informant sampling has some advantages over random sampling. One is that it is less costly than random sampling. For appraisal studies and low-budget feasability studies, key-informant sampling is preferable to random sampling, since it goes more directly, and at a lower cost, to those members of the community who are the most knowledgeable and who are the opinion leaders. Those sampled are more likely to have thought seriously about the issue and to be able to give meaningful judgments, to be capable of dealing with the hypothetical choices posed by judgment-based methods, and to be opinion leaders. This last fact means that their judgments may better predict the judgments of a future random sample than would the judgments of a present random sample and that value development in such representatives is more likely to lead, through their influence, to value development in the community.

Perhaps the single most compelling reason to employ key-informant sampling, instead of random sampling, is the Office of Management and Budget's restrictions on collecting information, the most recent statement of which is the notice of proposed rulemaking in the January 11, 1980 *Federal Register*. Section 1320.22 of this notice states, in part: "A Federal agency subject to the provisions of this subpart shall not collect information or sponsor the collection of information from ten or more persons unless, in advance, the agency has submitted to the Director of the Office of Management and Budget, and the Director has approved, the proposed collection of information." Because submitting a proposal is time consuming and approval is by no means assurred, one is often well advised simply to restrict sample size to fewer than ten. While such a sample size is rarely adequate when sampling is random, it can be adequate when sampling is directed toward key informants. (As just one example, by the standards applicable to random sampling, the city councils of most cities constitute very small samples of the populations they represent. Yet, because their method of selection is not, in fact, random, they are considered adequate.)

Methods for key-informant sampling are essentially the same as those for identifying publics: election or appointment to public office, identification by knowledgeables, self-identification, and snowballing. They have already been treated in the section on identification of publics.

Methods for random sampling are treated in various sources (e.g., Kish, 1965; Som, 1973). Help with random sampling can also be obtained from the Bureau of the Census. It must be kept in mind, however, that random sampling requires prior approval of the Office of Management and Budget.

Where larger budgets make it possible, it can be desirable to back up a key-informant value-judgment sample with a random sample. A sample of elected officials and a sample of randomly selected individuals will represent public values in different ways. While the sample of randomly selected individuals will provide an unbiased representation of the public in general, the sample of elected officials will tend to be weighted in favor of those who are politically more knowledgeable and effective. The values of both are important. While the value judgments of these two groups could simply be combined by some weighting scheme, it would seem preferable to identify and attempt to reconcile whatever differences may exist. One possibility would be to show the elected representatives the judgments of the randomly selected individuals and give them an opportunity to reconsider their initial judgments.

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Chapter 3: IDENTIFYING the ISSUES

The relationship of the task of identifying the issues to the overall structure of public planning decisions is shown in Figure 3.1:

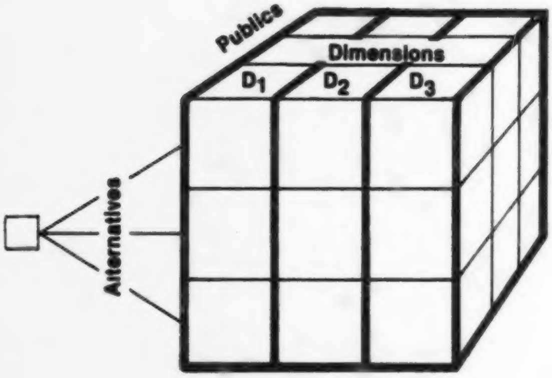

Figure 3.1. Identification of Issues

In formal terms, an issue is a question about location on a dimension, or a small set of dimensions: How much would a project benefit the regional economy? How great an effect would it have on fish and wildlife populations? Outcomes are generally characterized in terms of locations on a number of impact dimensions.

Since there is no set of impact dimensions that is appropriate for all studies, the task of identifying the issues has to be performed anew each time. The *Principles & Standards* (1973, p. 97) states that "The specification of the components of the objectives must reflect the specific effects that are desired by groups and individuals of the planning area as well as the specific components declared to be in the national interest by the Congress or by the executive branch through the Water Resources Council." The task of identifying the issues should be started early, in the scoping phase, before the set of alternative plans has been decided upon. Late introduction of environmental and social considerations, for example, tends to reduce their impact on the final decision (Ortolano, Brendecke, Price, & Meersman, 1978) and to put environmental and social scientists in a position where they are seen as obstructing, rather than facilitating, progress.

Two rather different subtasks are involved here: (a) identifying the important dimensions of impact, and (b) structuring the dimension set. Structuring the dimension set, in particular, is a task whose importance is seldom recognized and that is seldom carried out well.

Identifying the Important Dimensions of Impact

Identifying the important dimensions of impact, like identifying the impacted publics, is a creative thinking task. Both involve generating ideas. They are tasks that can perhaps best be accomplished together, or at least with considerable overlap. And they are tasks that can perhaps be best accomplished by public involvement specialists, working with a variety of publics (Creighton, 1980).

There are two steps in the task of identifying the important dimensions of impact. The first is to create a list that is as long as possible. No item should be missed, even if it seems redundant or foolish. Brainstorming sessions at public meetings or with a citizens' advisory committee, meetings with water knowledgeables (water officials, planners, politicians, representatives of the impacted publics), and content analysis of relevant documents (e.g., the agency's statement of planning objectives, statements of local interest groups, newspaper articles) all can contribute. The most useful of the various techniques for stimulating creative thinking (Stein, 1974, 1975) are applicable here: (a) varying stimuli to thought by means of checklists, conversation, and the passage of time and (b) keeping an open mind, recognizing that good ideas often seem foolish until one has had time to think about them.

A number of excellent checklists are available for bringing to mind possibly relevant dimensions. Two Presidential commissions have identified National goals (President's Commission on National Goals, 1960; National Goals Research Staff, 1970) The Technical Committee of the Water Resources Centers of the Thirteen Western States (1971) has developed a hierarchy of goals, subgoals, and indicators; a matrix of connections between decision variables and indicators; and a matrix of connections between indicators and subgoals. And the Water Resources Council's *Principles & Standards* provides an excellent checklist in its system of four accounts: NED, EQ, RD, and SWB, each of which can be divided into a hierarchy of categories and sub-categories. For example, EQ can be divided into the following categories and subcategories:

a. Areas of Natural Beauty
   Open and green space; wild and scenic rivers; lakes; beaches and shores; mountains and wilderness areas; estuaries.

b. Resources
   Archeological; historical; biological; geological.

c. Ecological Systems
   Water quality; air quality; land quality.

Each of the sub-categories is, in turn, further subdivided. Also, Battelle-Columbus has provided a list of environmental indicators (Whitman, Dee, et al., 1971); Battelle-Northwest has provided a list of social indicators (Olsen & Merwin, 1977); and a bibliography of social indicator research is available (Gilmartin, Rossi, Lutomski, & Reed, 1979.) Formal techniques for constructing hierarchies of dimensions are also being developed (e.g., Warfield, 1973.)

The second step in the task of identifying the important dimensions of impact is to obtain a tentative ordering of the items in terms of importance. This can be done by taking into account frequency of mention and the results of rating polls conducted at public meetings.

Structuring the Dimension Set

Structuring the dimension set is a critical thinking task. It involves elimination of ideas that are not consistent with certain requirements. It is not a task that would be easy to perform well in large public meetings, since it requires intensive interaction. (Data can be obtained at public meetings, however, that can be operated on by structural modelling programs to yield a first-cut structure; see, e.g., Kawamura & Malone, 1977). A well-structured set of dimensions has the following properties, the first three of which are analogous to the first three of those required for a well-structured set of publics:

Completeness,
Economy,
Nonredundancy,
Measurability,
Meaningfulness, and
Value independence.

Completeness requires that no important dimension be excluded; *economy* requires that no unimportant dimension be included. While completeness is also important in identifying the important dimensions of impact, economy is one of those requirements that does not become important until the dimension set has to be structured properly in preparation for quantification of values. It is desirable that the dimension set be kept as simple as possible, consistent with completeness, so that it can easily be presented for evaluation. A general rule of thumb is that a dimension set should contain no more than about eight dimensions. A dimension is considered to be important if (a) any of the alternative plans is expected to have an impact on it, and (b) some public would regard the expected degree of impact as having significant positive or negative value. A dimension is ordinarily not considered important, even if some public regards it as important, if none of the plans is expected to have any substantial effect on it. However, if a dimension is a major focus of controversy, it is probably wise to include it in any case.

Nonredundancy is the requirement that there be no double counting. Including both cause and effect is a common way of double counting. Income and standard of living would be an example. Income is of no value in itself; its primary value lies in the things it can buy, including things that are identified with standard of living. If a plan that leads to higher income is given a positive rating on an income dimension and a positive rating on a standard-of-living dimension, a single impact will have been counted twice.

A technique that can help to achieve completeness, economy, and nonredundancy is a *relevance tree*. A relevance tree branches downward from a single superordinate goal, such as social well-being, to increasingly subordinate goals relating to, say, the family, the community, and the natural environment. A relevance tree can be explored by means of "why" and "how" questions, "why" question moving one up the tree to more superordinate goals, and "how" questions moving one down the tree to more subordinate goals. For example, the question, "How can one imprpove social well-being?" might lead to the answer, "By improving the family, the community, and the natural environment"; and the question, "Why would one want to improve the community?" might lead to the answer, "To improve social well-being." (It should be noted that a relevance "tree" need not have a true tree structure; a given subordinate goal, such as increasing one's income, can contribute to more than one superordinate goal.)

Measurability and *meaningfulness* are required by the fact that the impact dimensions stand at the interface of what are called the technical analysis and the value analysis. The *technical analysis* projects the tree of cause-and-effect chains that is expected to be set into motion by implementation of a plan. It begins with first-order effects (construction, regulation of the flow of water, generation of electricity, provision of opportunities for recreation, etc.) and ends with changes on the impact dimensions (Income, Sense of Community, Safety, etc.) The *value analysis* is concerned with the worth, that is, the contribution to overall quality of life or social well-being, of changes on the various impact dimensions. It is at the impact dimensions (Income, Sense of Community, Safety, etc.) that the two analyses come together.

Measurability is the requirement that the impact dimensions relate to the *technical analysis*. It requires that each dimension be measured on a scale on which it will be possible to obtain projections of the effect of each alternative plan. Measurability should be judged by the appropriate technical experts, whether hydrologists, economists, biologists, or social scientists. Measurability is assessed in terms of reliability and validity, to be discussed later.

Even if a dimension that must be included for completeness can not be measured or measured well, it is still possible to obtain relevant value judgments by means of *proxy dimensions* (Keeney & Raiffa, 1976, pp. 56ff). A proxy dimension is a dimension that relates to the dimension of interest as cause or effect and is more readily measurable than the dimension of interest. For example, farm income is related as cause to the standard of living of farm families and is easier to measure. It will often be necessary to use proxy dimensions. Important dimsions that are difficult to measure are frequently encountered. To drop them from the dimension set would be to bias the analysis toward "hard" (engineering, economic) considerations and away from "soft" (environmental, social) considerations. The use of proxy dimensions makes it possible to include them. Because the proxy dimension is not the dimension of interest, however, the analyst must call the respondent's attention to the dimension that is to be judged and alert him/her to the imperfect relationship between the proxy dimension and the dimension of interest (Kahneman & Tversky, 1973).

Meaningfulness is the requirement that the impact dimensions relate to the *value analysis*, that is, that meaningful value judgments can be made about them. It requires that each dimension be measured on a scale that relates closely to the personal experience of the respondents. Meaningfulness should be judged by social science and public involvement personnel, working closely with the public. Because it is critical that impacts be measured in terms that are meaningful to the public, it is important to identify the relevant value dimensions before deciding on which dimensions to make technical projections of the impacts of alternative plans.

Value independence is, roughly speaking, the requirement that measured values on a dimension be substantially the same, no matter what the levels on the other dimensions. For example, the loss of one historical site should have the same value, no matter what the loss in game fish harvest. Conversely, the loss of 1000 pounds of game fish harvest should have the same value, whether or not any historical sites are lost.

Dimensions may be value independent over the ranges of potential impact even though they are not value independent over their entire ranges. If all the historical sites in an area were lost, a 1000-pound loss in game fish harvest might well be more serious than if no historical sites were lost. Perhaps more tourists would engage in fishing if there were no historical sites to visit, thus making the number of game fish more critical. The fact that value independence needs hold only over the ranges of potential impact (e.g., a loss of from 0 to 1 historical site) is a great help. It makes it far more likely that the dimensions will be found to be value independent.

An example of two dimensions that might not be value independent are the available supply of electric power and the size of the population. An increased availability of electric power might well be of greater value to a large community than to a small community. If value independence is found not to hold for certain dimensions, it may be possible to group these dimensions into a higher-order dimension that is value independent with respect to the remaining dimensions (Keeney & Raiffa, 1976.) For example, various combinations of population level and availability of electric power could be evaluated as a single dimension. Or a measure of power overage or shortage, such as generating power per capita, could be used.

Though value independence is usually found to hold reasonably well (Yntema & Torgerson, 1961), consideration should be given to the possibility that it does not, in which case one should seek to redefine dimensions in a way that achieves independence.

Selection of a Tradeoff Dimension

Though in many cases all dimensions will be considered relevant to all publics, this need not be the case. Some impacts may apply only to specified publics. It will be necessary, in any case, for at least one dimension to be included in the dimension sets of all publics in order that a basis be present for commensurating across publics in the second step of the cascade. In some cases, it may be necessary to add a dimension just for this purpose.

The use of a tradeoff dimension will be explained later. The only observation to be made here is that, while, in principle, any dimension could serve as a tradeoff dimension, trading off is considerably easier if one of the dimensions (a) has a large number of possible values, (b) is relatively important, and (c) is a dimension that the respondent is used to thinking in terms of. Money is an excellent dimension for this purpose. There would seem to be no dimension in terms of which people are so practiced in making quantitative judgments of value. Using money as a common tradeoff dimension has the additional advantage of facilitating comparisons with the results of market-based analyses. Income, taxes, and water user's fees are examples of suitable tradeoff dimensions.

While early contacts will be with representatives of the problem-structuring publics and will ordinarily be devoted to relatively unstructured discussions directed toward the identification of additional publics and representatives (Chapter 2) and impact dimensions (Chapter 3), later contacts will be with representatives of the value-judgment publics and will ordinarily be spent obtaining more precise information, in the form of scale value judgments (Chapter 4) and weight judgments (Chapter 5).

Chapter 4: MEASURING SCALE VALUES

Once the publics and issues have been identified, value judgments must be obtained on the dimensions of potential impact. When judgments are obtained on dimensions, the most widely accepted and employed technique requires two kinds of judgments: judgments of scale values (*V*'s) and judgments of weights (*W*'s). Scale value judgments are treated in this chapter, and weight judgments will be treated in the next chapter.

Both scale value judgments and weight judgments are judgments of value, in the broad sense. (The double use of the term "value" to mean worth and to mean a level on a dimension is accepted terminology. To reduce confusion, the term "scale value" will be used when referring to a level on a dimension of worth.) Scale values represent the relative worths, or values, of different positions along a given dimension. For example, a population increase would be welcomed up to some optimal level but not beyond that. Weights, on the other hand, represent the relative values of changes on different dimensions. For example, the reduction of flood damages that would result from a project might be considered to be twice as important as the damage to the riparian habitat that would result.

Figure 4.1 shows how measuring scale values for each public fits into the overall picture of policy decisions.

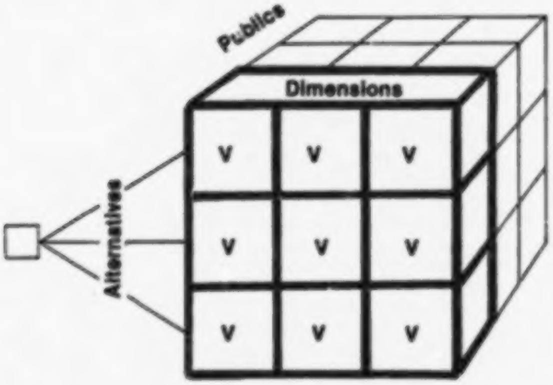

Figure 4.1. Measuring Scale Values

For each outcome, a scale value (*V*) must be measured on each impact dimension, and this must be done for each public. Value judgments, it will be recalled, provide the basis for commensuration. Note that it is not the person's personality, general value structure, or degree of satisfaction with life that is to be measured. All that is relevant to the decision are evaluations of those dimensions on which the outcomes of the various alternative plans are expected to differ.

One could ask for (a) value judgments of the anticipated *outcomes* (e.g., the outcome that farm income is $100,000, population is 2500, flooding does not occur; the outcome that farm income is $75,000, population is 1200, flooding occurs every 5 years; etc.) or (b) value judgments on *dimensions* that characterize the outcomes (e.g., the dimension of farm income, ranging from $50,000 to $200,000; the dimension of population, ranging from 1000 to 2000; the dimension of frequency of flooding, ranging from once a year to never.) Basically, the difference is between (a) obtaining judgments of the value of each of a limited number of point outcomes and (b) obtaining judgments of a value curve, or *function form*, that indicates the values associated with an infinite number of points within a specified range. The *Principles & Standards* (1973, p. 97) specifies that judgments be obtained on dimensions: "Rather than a single level of achievement being set forth for any specified component, a range of possible levels should [be] set forth so that the relevant preferences can be seen for a given component." Obtaining judgments on dimensions is preferable to obtaining judgments of outcomes, for two reasons.

The first reason has to do with *generality*. Judgments on dimensions permit generalization to any outcome within the range evaluated. Because impact projections are always subject to revision and new alternatives are often introduced, outcomes predicted by the final impact analysis may not correspond to those that were predicted when outcomes had to be selected for value judgment. If the outcomes in the fact and value analyses are not the same, it will then be impossible to relate the two analyses to one another and complete the evaluation of alternatives. Obtaining value judgments on dimensions greatly increases the chances that the value analysis will be applicable to the final impact analysis.

Also, because the impacts of any alternative are to some degree uncertain, it is often desirable to consider more than one possible outcome for some alternatives. Even if the fact and value analyses can be related to one another, analysis will be deficient if it fails to take account of important sources of uncertainty. (See Chapter 7.)

Generalizing to new outcomes is important for another reason, having to do with the requirement to consider mitigation measures. To the extent that mitigation measures are effective, they will lead to new outcomes; and these new outcomes must be evaluated in order to evaluate the mitigation measures.

The second reason why it is better to obtain value judgments of dimensions, rather than of outcomes, has to do with *reducing information load*: It is simpler to evaluate single dimensions than multidimensional outcomes. As pointed out in Chapter 1, the number of items of information that humans can process simultaneously is severely limited (Miller, 1956; Broadbent, 1975). As a consequence, information tends to be lost as the number of stimulus dimensions increases (Attneave, 1959; Einhorn, 1971). When making judgments of multidimensional stimuli, people tend to rely exclusively on one or two dimensions (Goldberg, 1965; Hoepfl & Huber, 1970; Hoffman, Slovic, & Rorer, 1968; Shepard, 1964; Slovic, Fleissner, & Bauman, 1972;

Slovic & Lichtenstein, 1971). (People seem to be unaware of the extent to which they rely on only a few variables. "This may be because they remember having attended, at one time or another, to each of the factors, but do not remember that they attended to no more than one or two at any one time"; Shepard, 1964, p. 266.)

Simply asking for judgments on dimensions will not necessarily solve this problem entirely. If dimensions are judged in the context of other dimensions, rather than separately, the presence of the other dimensions can lead to a judgment error known as the *halo effect* (DeSoto, 1960, 1961). If multidimensional outcomes are judged, outcomes judged to be high on a factor of central importance tend to be judged high on other factors as well (thus creating a "halo"). Similarly, outcomes judged to be low on the important factor tend to be judged low on other factors. The simplest way to eliminate this problem is to present dimensions separately for evaluation. (Of course, dimensions will have been considered in conjunction with one another in evaluating the dimension set for value independence.)

Obtaining value judgments on dimensions can also reduce the differences among the evaluations of different interest groups. Such groups usually differ less in their dimension-by-dimension judgments than in their outcome-by-outcome judgments (Gardiner & Edwards, 1975; Edwards, 1977). Presumably, this is because a major source of differences among such groups is that each focusses on a different subset of dimensions in evaluating multidimensional outcomes. Each is more likely to take the other's favored dimensions into account when judgments are obtained one dimension at a time.

(It is important to note parenthetically that it is a simple matter to obtain fact judgments after obtaining value judgments. After having obtained value judgments for various levels of, say, population, the analyst can simply ask the respondent what population levels he/she thinks would result under each of the alternatives. Comparison of public fact judgments with expert fact judgments can reveal areas of misinformation, which can then be targetted in public involvement information efforts. It is also possible, of course, that such a comparison will bring new facts or a different perspective to the attention of the experts and thus lead to a change in their fact judgments.)

Interval-Scale Measurement

Commensuration involves the comparison of *differences*. The method to be described in the following chapter involves attaching importance weights to differences on various dimensions. If this weighting process is to be meaningful, however, the differences on which it is based must also be meaningful. For this reason, measurement of scale values on individual dimensions must accurately reflect differences. Measurement of scale value must be on what is called an *interval scale* (Hobbes, 1979, p. 126).

It will be important throughout this paper to distinguish among various levels of scales of measurement (See Brown, Quinn, & Hammond, 1980.) Dimensions can be measured on different scales, as the dimension of temperature can be measured on the Fahrenheit, centigrade, or absolute (Kelvin) scales. Furthermore, scales can be classified on the basis of the level of measurement achieved, degrees Fahrenheit and degrees Celcius being measured at what is called the interval-scale level and degrees Kelvin being measured at what is called the ratio-scale level. The most useful distinctions for present purposes are among ordinal, interval, and ratio scales. These distinctions among scale levels are based, not on the numbers, themselves, but on the procedures used in assigning the numbers to objects.

An *ordinal scale* indicates only whether quantities are greater than, less than, or equal to one another. The scale of plusses, zeros, and minuses is generally an ordinal scale, as are scales like "improvement/no change/degradation"; "good/fair/poor"; etc. Ordinal scales do not represent differences for the very simple reason that the scaling procedure for obtaining an ordinal scale does not require the respondent to assign scale values in such a way that equal numeric differences along the scale will correspond to equal differences along the dimension.

The usefulness of an ordinal scale in decision making is restricted to (a) pass-fail, or cut-off, screening and (b) the elimination of dominated alternatives. *Cut-off screening* is employed in the early elimination of unacceptable alternatives. Strictly speaking, it is appropriate only where an unsatisfactory value on the screening dimension can not reasonably be expected to be compensated for by high values on other dimensions. The most clearly appropriate bases for cut-off screening are legal requirements, for it is mandatory that these be satisfied. Examples are the population density requirements and habitat requirements regarding endangered species.

A second use for ordinal scales is the *elimination of dominated alternatives* (Pareto, 1927; Cohon, 1978). A dominated alternative is one for which there is at least one alternative that is superior on at least one dimension and inferior on none. Consider the following simplified decision situation:

	A	B
Plan I	++	+
Plan II	+	+

Plan I has been given a higher rating than Plan II on dimension A and the same rating as Plan II on dimension B. No matter how great or small the interval between the + of Plan II and the ++ of Plan I on dimension A, the choice would be the same: Implement Plan I. Interval information is irrelevant here.

Though few decisions are so easily resolved, it is often the case, especially when the number of alternatives is large in comparison with the number of dimensions, that some alternatives are dominated and can be eliminated in this fashion. Also, as will be discussed later, it may be possible by means of mitigation measures to create an alternative that dominates all others.

Seldom, however, can all alternatives but a single one be eliminated on the basis of ordinal scale values. Consider the following simplified decision situation:

	A	B
Plan I	+	-
Plan II	-	+

Here, neither alternative is dominated by the other. Whether Plan I or Plan II is, on balance, preferable depends on whether the difference in favor of Plan I on dimension A is greater or less than the difference in favor of Plan II on dimension B. It is not possible to choose either plan without making an assumption about the relative magnitudes of these intervals.

Note that this is also true in the following case:

	A	B	C	D	E	F
Plan I	+	+	+	+	+	-
Plan II	-	-	-	-	-	+

Even though five dimensions favor Plan I and only one favors Plan II, the magnitude of the single difference in favor of Plan II could be far more important than the magnitude of the sum of the differences in favor of Plan I. For this reason, the common practice of "counting plusses" (the Copeland criterion; see Goodman, 1959) is not generally defensible.

The relative importance of an interval on one dimension and an interval on another is referred to as the *tradeoff* between these two dimensions. (Actually, there are two meanings for the term "tradeoff". The first could be called "objective tradeoff". It is the amount one *must* give up on one dimension in order to achieve a given amount on another dimension. The other could be called "value tradeoff". It is the amount one is *willing* to give up on one dimension in order to achieve a given amount on another dimension. The first is a matter of fact; the second, a matter of value. In this paper, the term "tradeoff" will always refer to value tradeoffs.) *Virtually all decisions of the complexity of those involved in Federal water resources planning involve judgments about the relative importance of intervals on different dimensions. Tradeoffs are virtually always involved. It is the making of tradeoffs that requires measurement on an interval scale and commensuration.*

An all too common error is to perform arithmetic operations on ordinal scales. The arithmetic operations of addition, subtraction, multiplication, and division are meaningful only with scales that have a meaningful unit of measurement. To see what can happen when arithmetic operations are performed on ordinal scales, consider the following example (Plott, 1976). Four alternatives have been rank-ordered on seven dimensions as follows. (Higher numbers indicate more favorable impacts.)

	D1	D2	D3	D4	D5	D6	D7	Sum
A1	4	1	2	3	4	1	2	17
A2	3	4	1	2	3	4	1	18
A3	2	3	4	1	2	3	4	19
A4	1	2	3	4	1	2	3	16

Although the judgments were obtained on only an ordinal scale, they have been added up, a common erroneous practice.

It is instructive to see what would have happened if Alternative 4 had not been included in the analysis. Since Alternative 4 is the least preferred alternative, anyhow, one would expect that excluding it would have no effect on the relative ordering of Alternatives 1, 2, and 3.

The next set of figures shows that, even though this expectation is correct for the dimension-by-dimension rankings, it is not necessarily true for the aggregate ranking based on these.

	D1	D2	D3	D4	D5	D6	D7	Sum
A1	3	1	2	3	3	1	2	15
A2	2	3	1	2	2	3	1	14
A3	1	2	3	1	1	2	3	13

Whereas, before, the ordering was A1 < A2 < A3, it is now A3 < A2 < A1, *exactly the reverse*. Performing arithmetic operations on ordinal data can be dangerous. Performing arithmetic operations assumes at least an interval scale.

Whether a particular 0-to-5 scale, for example, is an ordinal scale or an interval scale depends on how the numbers were assigned. If the respondent was instructed simply to assign the numbers in such a way that a 3 is assigned to quantities that are greater than those assigned a 2, a 2 is assigned to quantities that are greater than those assigned a 1, etc., it is an ordinal scale. If, however, the respondent was instructed to assign numbers in such a way that quantities assigned a 3 are as much greater than those assigned a 2 as quantities assigned a 2 are greater than those assigned a 1, etc., it is an interval scale. An interval scale represents, not only ordinal relationships among quantities, but also relationships among differences between quantities. (Consistency checks on the intervals, to be discussed later, are also an important part of the interval scaling procedure.)

It is a frequent objection that interval judgments are difficult or impossible to make.. The fact is, if tradeoffs are involved, interval judgments *will* be made whether explicitly or implicitly. Even if one "counts plusses", one implicitly makes an assumption about intervals, that all plusses represent intervals of equal importance. "...There are no incommensurables when decisions are made in the real world" (Stokey & Zeckhauser, 1978, p. 153). Assumptions about intervals should not be left implicit but should be made explicit and, moreover, should be verified by interval scaling procedures.

Judgment Methods

Two methods will be described for measuring scale values: (a) *straight-line approximation* to function forms and (b) *function form judgment*. "Function form" is a general concept referring to the form of the functional relationship between two variables. Graphically, it is the shape of the curve that represents that relationship. Figure 4.2 illustrates the most frequently encountered function forms. The function forms considered here always take objective scale values (plotted on the horizontal axis) as input and return subjective scale values (plotted on the vertical axis) as output. They thus transform the objective terms of the technical analysis into the subjective terms of the value analysis.

In order to read values from a function form, one locates on the horizontal axis the projected impact for each of the various alternatives; draws a vertical line from this point to the function, or curve; and draws a horizontal line from this intersection to the vertical axis, where the value judgment is read off.

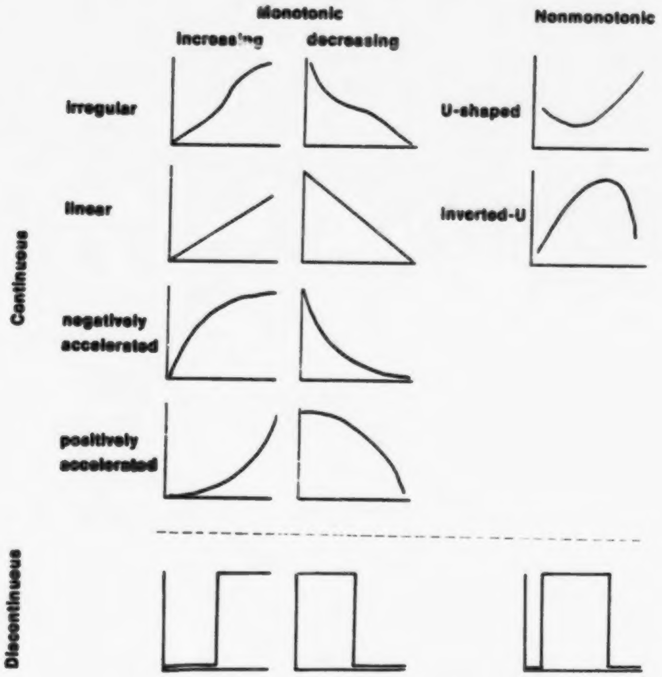
Monotonic
increasing
decreasing
Nonmonotonic
irregular
U-shaped
linear
inverted-U
Continuous
negatively accelerated
positively accelerated
Discontinuous

Figure 4.2. Common Function Forms

The straight-line method is the less costly of the two in terms of time and effort and may provide an approximation to interval-scale measurement that is adequate for most dimensions (Gardiner & Edwards, 1975). However, so long as the actual function forms are not measured, there is no check on this assumption. Function form judgment, while somewhat more costly, provides an interval scale that is theoretically justified and that can be verified empirically. It is the recommended method. The straight-line method is presented simply as a low-cost alternative.

Straight-line approximation to function forms (Gardiner & Edwards, 1975; Edwards, 1977) is accomplished as follows. The most and least preferred values on the objective scale are identified. A point is plotted above the most preferred value at the top of the graph; a point is plotted above the least preferred value at the bottom of the graph; and a straight line is then drawn between these points. If either end of the objective scale is intermediate in value (i.e., if the function form is non-monotonic), the subjective value of this intermediate point is determined, and this point is connected by a straight line to the rest of the graph.

Often, straight-line approximation can be accomplished by agency personnel without involving the public. For example, it seems reasonable to assume that the highest income that could result from any of the alternatives would be the most highly valued and that the lowest income that could result from any of the alternatives would be the least valued. It may also be a reasonable assumption that a straight line drawn between these values will produce estimates of intermediate values that will not be far from the true values (Gardiner & Edwards, 1975; Edwards, 1977; Huber, 1974). By having agency personnel estimate scale values in this way, attention in the assessment of public values can be focussed on the weight judgments, which is where individual judgments are most likely to differ (Gardiner & Edwards, 1975).

The recommended method for measuring values on an interval scale is function form judgment (Yntema & Torgerson, 1961). The advantages of having representatives of the public judge the function forms, instead of having agency personnel approximate them with straight lines, are that (a) more accurate function forms should be obtained and (b) function-form judgment helps "warm the respondent up" for weight judgments.

Prior to meeting with the respondents, attention should be given to the careful preparation of stimulus materials. For each dimension, a range of possible impacts has to be presented for judgment. This range must be broad enough to include any likely future and should include the present conditions value. It is advisable to prepare a separate sheet of paper for each dimension with the name of the dimension at the top and the labelled axes of a graph below. See Figure 4.3. The horizontal axis represents possible levels of impact (here, farm income levels of $50,000; $100,000; $150,000; and $200,000), and the vertical axis, labelled "more preferred" at the top and "less preferred" at the bottom, represents associated levels on the value dimension. The arrow on the horizontal axis indicates the present conditions value (in this case, for this particular respondent's income class) on that dimension. (The purpose of representing each dimension on a separate sheet of paper is to facilitate the judgment of weights by enabling the respondent, at that later time, to arrange the dimensions in order of importance.)

Once the judgment materials and elicitation procedures have been tentatively decided upon, they should be checked for bias with the various problem-structuring publics. Special interest groups will be quick to spot factors (whether real or imagined) that might bias the judgments against their position. Collectively, they can be a real help in calling attention to potential sources of bias, particularly in suggesting a variety of meaningful referents for positions along the objective scales of impact.

The first step in obtaining judgments is a *get-acquainted and warm-up phase*. "Getting acquainted" is important for reducing interviewer effects. Interviewer effects are differences between behavior that occurs in the presence of the interviewer and behavior that occurs in more normal circumstances (Webb, Campbell, Schwartz, & Sechrest, 1966, pp. 12-23). Simply allowing a period of friendly, relaxed interaction will itself reduce the novelty of the interviewer. In addition, the greater the number and strengths of identifying links (including common responses to the weather!) that the interviewer can establish between him/herself and the respondent, the greater should be the reduction in interviewer effects. (Because interviewer effects are greater the greater the differences between the interviewer and the respondent on such salient variables as race, social class, sex, and age, an attempt should be made to match interviewers to respondents on any such variables on which differentially impacted publics differ, for example, having Indians interview Indians and non-Indians interview non-Indians.)

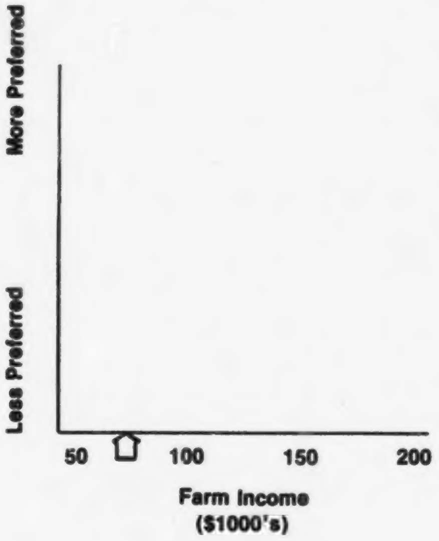

Figure 4.3. Graph for Function Form Judgment

"Warm up" is a matter of activating those memories, skills, and attitudes that are conducive to performing the judgment task well. To begin with, the purpose of the data collection effort and the use to which the judgments will be put should be explained to the respondent:

Assessment of public values gives the public (and the respondent, especially) a greater voice in public decisions; quantification assures that the judgment of every respondent will be reflected in the final figures. It should also be made clear that participation is voluntary and that all responses will remain anonymous, or at least confidential. (When the representatives are elected or appointed officials, however, assurance of anonymity and confidentiality would, of course, be inappropriate.)

(At some point in the interview, it will be necessary to determine the respondent's approximate income level, if income is the tradeoff dimension to be used in the commensuration across publics. Since income tends to be a sensitive subject, it is probably best to treat the respondent as a representative of a category and to ask for an estimate of the average level of income of people in that category. The respondent should be instructed to make judgments from the point of view of someone at that average level of income.)

The value dimensions should then be introduced and discussed until it is clear that the respondent has understood them and has had time to start thinking about the implications of high and low values on each. This requires talking through various scenarios. Though it is important to get quantitative judgments eventually, it is also important to spend time verbally exploring relevant experiences and thoughts before obtaining these judgments. (The following hypothetical conversation between an interviewer, designated by the letter "*I*", and a respondent, designated by the letter "*R*", is included for illustration. Other such hypothetical conversations will be interspersed throughout these discussions.)

> *I:* In order to find out what kind of place you'd like Farmington to be, I'm going to ask you some questions about income, population, flooding, scenic beauty, and recreation. [Spreads labelled function form graphs out on table to provide an external memory aid for directing the discussion.] I'll explain these graphs in a bit, but first I'd just like to talk to you about these things and about Farmington.
>
> *R:* Well, I'm for the dam, if that's what you want to know. We need the water in the summer, and we've sure got more than we need in the winter. It's as simple as that.
>
> *I:* That's the kind of thing I need to know. The water in the summer would help you with your farm and give you a better income. Flood control would also help you financially by saving you the costs of flood damage, but over and above that it would reduce inconvenience and danger. When we're talking about income, we'll be talking about the income you receive from selling your crops. When we talk about flood damage, we'll be talking about both the dollar costs of flood damage and the psychological costs of inconvenience and danger.

> What kind of experiences have you had with flooding?
>
> *R:* Well, I've been flooded out, off and on, since I was a kid on my dad's farm....

Expressed attitudes predict actual choices only to the extent that the evaluated items are meaningfully related to the respondent's experience (Ajzen & Fishbein, 1977; Gross & Niman, 1975; Wicker, 1969). Because of this, levels on dimensions should be defined clearly and in terms that relate concretely to the respondent's experience. For judgments on such dimensions as scenic beauty, drawings or photographic representations can help; for judgments on such dimensions as population, population maps or other graphic representations can be appropriate. The dimensions should be anchored by identifying meaningful values on each (that is, meaningful positions along the horizontal scale). The ends of the scale should be anchored, and the identification of the present-conditions value provides a particularly meaningful anchor. On many scales, such as number of violent crimes or deer population, a true zero provides an additional anchor.

> *I:* The population dimension varies from 1000 to 3000. [Points to horizontal axis on population graph.] The current population of this area is about 1500. Four Corners and High Rocks are about 1000, and Amity and Pikesville are about 3000. The population around here could change, and we'd like to know how you'd feel about different population sizes for this area.
>
> *R:* The population should be a little bigger than it is now, but not too much.
>
> *I:* What are some of the good things that you think population growth might bring?
>
> *R:* More facilities. If we had more people, we could get a hospital and a supplier.
>
> *I:* What are some bad things that you think population growth could bring?
>
> *R:* Well, until things got caught up, there'd be a housing problem, I guess. Also, there'd be some adjustment to newcomers, and things'd probably always be a little less personal.
>
> *I:* Would you want any more population than would be necessary to support a hospital and a supplier?
>
> *R:* No. That's all I'd want.
>
> *I:* What size population do you think that'd take.
>
> *R:* A couple of thousand, I'd guess. The smallest town around here with a hospital is

> Neighborsville, and they have about a couple of thousand. That'd be more than enough to keep a supplier in business.

The respondent should be directed to keep in mind the contexts in which the consequences being evaluated will actually be experienced. For example, population increases might be thought about in the context of work, recreation, transportation, community government, and the like. It is crucially important that the respondent's memory and imagination be stimulated in ways that will help bring the appropriate contexts to mind. For help in formulating questions that will do this in a complete and unbiased manner, it is advisable to discuss the questions in advance with representatives of the various problem-structuring publics. Questions put to the respondent should be framed, insofar as possible, as concrete choices, and the respondent should be motivated to treat the choices realistically and seriously.

> *I:* It's important that you think hard about these questions, because if you say you want a town of 2000, the decision might be to try to do something that would create a town of 2000. It's important, also, that you indicate what you really want, not just what you think might get the dam put in, because there are other decisions involved besides the dam. Whatever plan is decided on, thought will be given to taking other steps to make things even more the way people around here say they would like them. If people say they want a high population just to get the dam put in and the decision is made to put it in, other measures may be taken to get the population even higher, since that's what folks said they wanted. The best thing to do is simply to tell us what you really want.

Adequate motivation reduces the reliance on "mental shortcuts" that introduce biases into judgments (Slovic, Lichtenstein, & Edwards, 1965) and, if properly induced, should also reduce gaming.

It is easier to think of pleasant or confirming cases than unpleasant or disconfirming & Mann, 1977; Wason & Johnson-Laird, 1972). (A disconfirming case is one that would tend to contradict the respondent's beliefs or to argue against a course of action that the respondent prefers.) It has frequently been found helpful to ask the respondent to think through in vivid detail one or more "worst possible" scenarios, scenarios different from those expected, or scenarios inconsistent with a preferred course of action. It is also easier to think of events the more recently or frequently they have been encountered (Tversky & Kahneman, 1973). Consequently, the respondent should be asked to try to think about relevant experiences that are both near and remote in time and relevant experiences that have occurred both frequently and infrequently.

> *I:* What's the worst thing you think could happen around here?

> *R:* Oh, I suppose tearing up good farm land and putting in tract homes or factories.
>
> *I:* What's the worst thing that's happened around here in the past?
>
> *R:* Droughts and floods. Come to think of it, the worst thing that could happen would be a major drought. That could put me and the other farmers here right out of business.
>
> *I:* What is the worst thing that could result from putting a dam in?

Function-form judgment, itself, proceeds as follows. Each dimension is reintroduced and discussed briefly, and the present conditions value is identified. (See Figure 4.3.)

> *I:* O.k., now I want to ask you some more detailed questions about each of these dimensions. On each of these pieces of paper there's a graph. The dimension to be judged is marked on the horizontal line, like income here. The vertical line says "more preferred" at the top and "less preferred" at the bottom. Now, remember, income means the money you make in a year from selling your crops. The dimension runs from $50,000 to $200,000, and your present income is about $75,000.
>
> *R:* Before taxes, it is.
>
> *I:* Yes, before taxes. All these figures are before taxes.

The respondent is asked, for each direction of change from the present conditions, whether such a change would be favorable or unfavorable and why. Then he/she is asked to indicate the least and most favorable values on the dimension, within the range presented. The least favorable value is assigned a rating at the bottom of the subjective rating scale, and the most favorable value is assigned a rating at the top of the subjective rating scale. (See Figure 4.4.)

> *I:* The first question I'm going to ask you about each dimension is where the best level is and where the worst level is. For some dimensions, like income, this will be pretty obvious. For others, like population, it won't be.
>
> *R:* Income is easy. The more the better.
>
> *I:* Sure. So at $50,000 I'm going to put a point at the bottom of the graph, and at $200,000 I'm going to put a point at the top of the graph, like this.

The information requested to this point has been simply ordinal. The next set of questions asks for interval information. If the function form is *monotonic* (i.e., if subjective value is judged either to increase or to decrease across the full range of the objective dimension), the objective value corresponding to a rating in the middle of the subjective scale is also established, to determine more precisely the form (rectilinear or curvilinear) of the function. The method is always one of searching for some *indifference point*, some point at which two intervals are judged to be equal in value. (See Figure 4.5.)

> *I:* Now, let's say there are two farmers. One has an income of $50,000, and the other has an income of $125,000. Both get an increase of $75,000, so that the one who was making $50,000 is now making $125,000, and the one who was making $125,000 is now making $200,000. Which one would be happier about his increase?

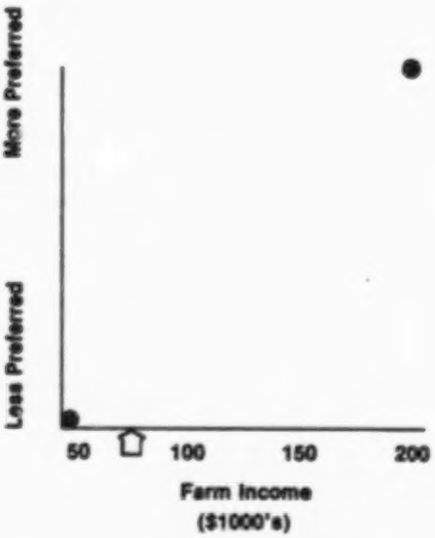

Figure 4.4. Plotting High and Low Values on a Function Form

> *R:* The one who was making $50,000. He needs the money more.

> *I:* Sounds reasonable. Now, say that the first farmer was making $50,000 and the second was making $75,000 and that the one who was making $50,000 moves up to $75,000 and the one who was making $75,000 moves up to $200,000. Which do you think

would be happier?

R: Well, in this case, I think the one who went to $200,000. That's a big difference.

I: Sure. Now, what if one went from $50,000 to $100,000 and the other went from $100,000 to $200,000?

R: I think it'd make more difference to the first guy. I think $50,000 to about $90,000 would be about the same as $90,000 to $200,000.

I: O.k. Good. So at $90,000 I'm going to put a point halfway between the top and the bottom of the graph, and I'm going to draw in a curve, like this. The curve bends over, showing that increases make more of a difference for the poor guy than the rich guy.

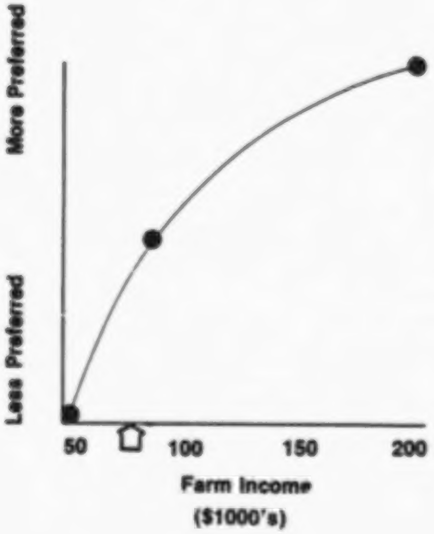

Figure 4.5. Plotting the Middle Value on a Function Form

R: That looks about right to me.

(Note that the curve is not a straight line. Equal dollar amounts are valued differently depending on where one is on the curve. The value of a given monetary increase tends to decrease as total assets increase, exhibiting what is called *decreasing marginal utility*. As has already been noted, market-based methods that do not take this into account and that assume a one-to-one relationship between dollars and value are, as a general rule, flawed.)

Note that this method directs the respondent to consider intervals. This is essential if measurement on an interval scale is to be achieved. This method of judging whether two intervals are or are not equal, called *bisection* (Guilford, 1954; Torgerson, 1958; Fishburn, 1967), is both the oldest and the least demanding of the various quantitative judgment methods. As such, it should be less subject to error, particularly to error resulting from the context provided by the particular stimuli selected (Torgerson, 1958, pp. 56, 103, 117ff; see also Guilford, 1954, p. 312; Parducci, 1963, 1965, 1968). More will be said about such errors later.

In phrasing the questions put to the respondent, it is important to keep in mind two common response sets: acquiescence and evasiveness (Cronbach, 1967). *Acquiescence* is the tendency to say "yes" in preference to "no". It can be avoided simply by avoiding questions that can be answered "yes" or "no", that is, by not suggesting an answer to the respondent. *Evasiveness* is the tendency to say "don't know" in preference to giving any more definite response. It can be avoided by not allowing "don't know" or "no difference" as answers, that is, by using forced-choice questions. Asking questions of the form, "Which farmer do you think would be happier?" or "Which would you prefer?", satisfies both requirements.

The indifference point that results from a decreasing series tends not to be the same as that which results from an increasing series (Guilford, 1954; Baird & Noma, 1978). Alternating between values that are too high and values that are too low and thus gradually closing in on the indifference point from both directions helps to avoid such *order effects*. Because the initial set of bracketing stimuli provide judgmental anchors that are likely to influence the indifference point (Tversky & Kahneman, 1974), it would be better to ask the respondent for initial bracketing values than to suggest any. However, within the bracketed range, it may be better to suggest values for the respondent to choose between (as in the preceding dialogue) than to ask for values (MacCrimmon & Siu, 1974).

If the function form turns out to be *nonmonotonic* (i.e., if subjective value is judged to increase across one part of the range of the objective dimension and to decrease across another, making the function form either "U" shaped or "inverted U" shaped), and if one endpoint of the curve lies between the top and bottom of the subjective scale, the subjective rating of that end of the curve should also be determined.

> *I:* O.k. You've told me that 2000 would be an ideal population for this area, and we put that at the top of your scale [see Figure 4.6]. And you told me that 1000 would be the worst, and we put that at the bottom of your scale. Now, what I need to know is where a population of 3000 should go. Would it be closer to the good level of 2000 or closer to the bad level of 1000?

R: Closer to 1000.

I: More like halfway between 1000 and 2000, or more like 1000?

R: More like halfway.

I: About here on the graph? [See Figure 4.7.]
R: Yes. That seems about right.

Income and population are, for all practical purposes, *continuous* dimensions; there are many more possible levels on each than a respondent can discriminate. Other dimensions, however, are *discontinuous*. An example might be scenic beauty. Assume that the alternative plans are nonstructural changes, channelization, and construction of a dam in either of two locations (call them Dam A and Dam B). It is not easy to place these levels of impact on a continuous dimension. The nonstructural alternative would involve no impact on scenic beauty, but the channel and the dams would involve changes that would actually differ on a number of dimensions. It is simplest to construe them as discontinuous levels on a single dimension of scenic beauty.

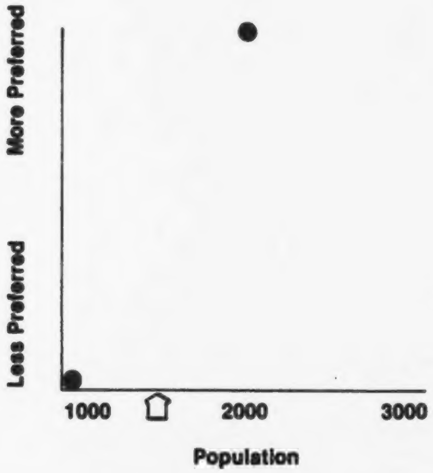

Figure 4.6. Plotting High and Low Values on a Nonmonotonic Function Form

With discontinuous dimensions, it is not possible to vary intervals hypothetically until an indifference point is reached. For example, while one can specify a population that is objectively 1/4, 1/2, 3/4, etc. of the way between 1000 and 3000, one can not easily specify a level on any dimension corresponding to aesthetics that is objectively 1/4, 1/2, 3/4, etc. of the way between a channel and a dam. Instead of adjusting intervals until their values are equal (in the ratio of 1:1), it is necessary to have the respondent estimate the ratios of the values of the existing intervals. This method, called *ratio estimation*, places greater demands on the respondent.

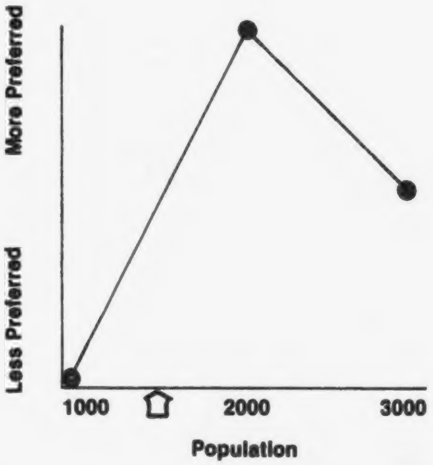

Figure 4.7. Plotting an Intermediate End Value on a Nonmonotonic Function Form

I: Which of the four alternatives, nonstructural, channelization, Dam A, or Dam B, do you feel would be most aesthetically desirable? Assume that all alternatives will have identical impacts on income, population, etc.

B: Nonstructural, because it wouldn't change anything.

I: And which would be the least aesthetically desirable?

R: Dam B. Dam B would be the worst, then Dam A, then the channel, and then the nonstructural alternative.

I: O.k. Now, what is the biggest difference among the adjacent alternatives in this ranking?

R: The difference between channelization and Dam A.

I: And which is the smallest?

R: The difference between the two dams.

I: O.k., now I have a harder set of questions. How much bigger is the difference between channelization and Dam A than the difference between the nonstructural alternative and channelization?

R: Wow! I'm not sure I know how to answer that.

I: Let me put it this way. Assume that there are two areas just like Farmington. They are planning to put a channel in one, and they are planning to put a dam like Dam A in the other. O.k.?

R: O.k.

I: In each case, though, there is a more expensive alternative, a nonstructural plan in place of the channel and a channel in place of Dam A, that would achieve the same results in terms of income, population, etc. O.k.?

R: I'm with you.

I: Fine. Now, the first question is, If you were living in the first area, imagine how strongly you'd feel about going from the channel to the nonstructural plan--how much work you would be willing to put in, how much money you would be willing to pay. Let this line length represent that strength of feeling. [Draws a line of arbitrary length.]

R: O.k.

I: Now, if you were living in the second area, imagine how strongly you'd feel about going from Dam A to the channel--how much work you would be willing to put in, how much you would be willing to pay. Draw a line that represents that strength of feeling.

R: O.k. [Draws line.] I think that's about right.

Because ratio estimation, unlike bisection, requires the respondent to produce judgments on a scale with many values, additional problems are introduced that the method of bisection was able to avoid. One of these is the *error of central tendency*. Respondents tend to give judgments that are too near the center of the response scale; high objective values tend to be given subjective values that are too low and low objective values tend to be given subjective values that are too high (Guilford, 1954). The farther the objective value is from the center of the distribution, the greater is this tendency. The error of central tendency is a serious one because it tends to make the intervals unequal. The easiest way to deal with this error is to present stimuli that do not require extreme judgments, in this case adjacent intervals on the stimulus dimension.

Two additional problems are round number bias and memory effects. *Round number bias* refers to the fact that certain numbers, such as 10, 20, and 30, tend to be given as judgments more frequently than others, such as 11, 29, and 54. *Memory effects* refers to the fact that, when a stimulus is repeated, it is easier to recall an earlier judgment of that stimulus and simply repeat it if the judgment is a number. *Graphic rating*, having judgments made in terms of line lengths rather than numbers, avoids both problems (Anderson, 1974).

Whether bisection or ratio estimation is used, the judgment of a stimulus usually depends to some extent on how early or late in the sequence it is judged and on what particular stimuli it follows (Baird & Noma, 1978; Guilford, 1954). Judgment is subject to *order effects*. Because of this, the order in which the stimuli are judged should be varied. For example, toward the end of the sequence, the stimuli judged at the beginning should be judged again. The extent to which subsequent judgments differ from earlier ones should provide an indication as to how long this process should be continued. (This is also why the respondent is introduced to all the dimensions before judging any dimension, to reduce order effects.)

Throughout the judgment process, reasons should be obtained for judgments as a check on the respondent's understanding of the instructions and the meaningfulness of his/her judgments. Also, apt expressions of reasons for various judgments ("quotable quotes") should be recorded for use in the presentation of the results, since they add meaningfulness to abstract statistics (Borgida, Crandall, & Reed, 1976).

Measurement Error

It is important that the person obtaining the judgments have an understanding of kinds of error, sources of error, and ways to reduce error. (See Brown, Quinn, & Hammond, 1980.) There are two kinds of error in measurement: random and constant. Though error from any particular source may be mixed, it can always be analyzed into random and constant components.

Random error. Random error is error that changes unsystematically in direction and magnitude on repeated measurements. See Figure 4.8. If one thinks in terms of the analogy of a rifle that is being bench tested, random error refers to the scatter produced by repeated shots. Random error is a matter of lack of precision or reliability.

Random error can be measured in terms of such statistics as a range, a standard deviation, or a confidence interval. Alternatively, a correlation coefficient can be computed between the numbers assigned to the same objects on two different occasions (test-retest reliability) or between the numbers assigned to the same objects by two different respondents (inter-rater reliability.)

However, the important question is, not how great random error is in terms of some statistic, but how great its effect is on the decision. This question can be answered by performing a sensitivity analysis on the effects of variations within the confidence interval. Confidence intervals and sensitivity analysis are discussed in Chapter 7: Uncertainty, Information, and Utility. If the overall ranking of the alternatives is unaffected by variations within the confidence interval, the decision is insensitive to that amount of random error. If, on the other hand, the overall ranking of the alternatives is changed by such variation, consideration should be given to the desirability of reducing random error. This matter, also, is discussed in Chapter 7.

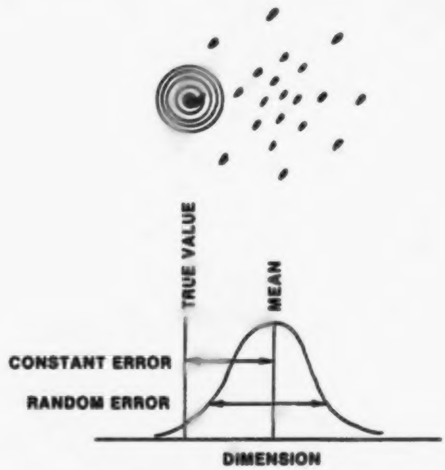

Figure 4.8. Random and Constant Error

Random error in judgments can be reduced by introducing controls, such as increasing the standardization of judgment elicitation procedures, but care should be taken not to introduce controls, such as restricting the range of publics sampled, that would introduce constant error and limit the generality of the results. Perhaps the safest way to reduce random error in judgments is simply to increase the number of judgments and average them. (A decision policy based on the average of several judgments made by a person usually outperforms the person, himself, in making individual decisions (Goldberg, 1970; Dawes & Corrigan, 1974; Yntema & Torgerson, 1961.))

Constant error. Constant error is error that is constant in direction and magnitude on repeated measurements. In terms of the bench-testing analogy, constant error refers to the difference between the center of the scatter and the target. (See Figure 4.8.) It is a matter of lack of accuracy or validity. Constant error can be measured in terms of the difference between the judged scale value and

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the true scale value, if it is known, or the correlation between a set of judged scale values and the corresponding true scale values, if they are known. The correlation between a set of judged scale values and a set of true scale values is referred to as concurrent validity if the true scale values are measured concurrently with the judgments, postdictive validity if they were measured in the past, and predictive validity if they will be measured in the future. (See Brown, Quinn, & Hammond, 1980.) If there is no single scale of validity, as in the case of such abstract dimensions as "community cohesion", "scenic beauty", and "recreation value", so that correlation with a number of sets of measures is required, the set of correlations is referred to as construct validity. (See Brown, Quinn, & Hammond, 1980.)

The important question about constant error, as about random error, is not how great the error is in terms of some statistic, but how great its effect is on the decision. This question can be answered in the case of constant error by performing a sensitivity analysis on the effects of applying various correction factors.

However, the problem with any of these methods for evaluating constant error is that the true scores, and hence the appropriate correction factors, are usually difficult or impossible to determine. This is especially true when it is values that are being measured. Because constant error in measurement is more difficult to detect than random error, it is more serious.

More is known about the general causes of constant error than about the true values that might apply in any specific situation. Consequently, it is easier to take steps to avoid constant error than it is to measure it. Constant error in judgment results from the violation of methodological assumptions (e.g., the assumption that it is intervals that were judged) or from psychological biases. Ways to satisfy methodological assumptions are discussed in connection with those assumptions, and techniques for avoiding psychological biases (interviewer effects, irrelevance of judgments to actual preferences, the halo effect, recency bias, pleasantness bias, context effects, order effects, rounding error, memory for prior responses, acquiescence response set, and evasiveness response set) have been incorporated into the judgment procedures.

Chapter 5: MEASURING WEIGHTS

Weight judgments are judgments of the relative importance of unit changes on different scales of measurement and are the basis for transforming scale values on different scales into scale values on a common scale. Weight judgments are the basis for commensuration in the first step of the cascade. Figure 5.1 shows how measuring weights relates to the overall structure of planning decisions.

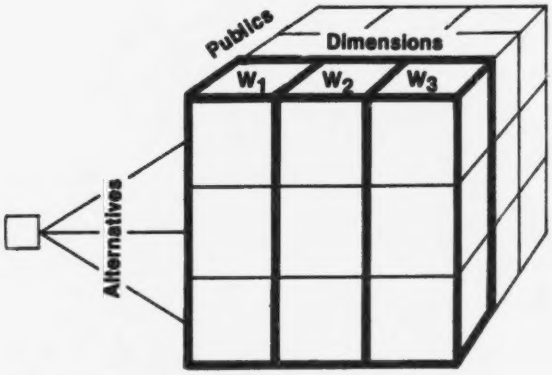

Figure 5.1. Measuring Weights

A weight must be obtained for each dimension, and this must be done for each public.

Ratio-Scale Measurement

Weights are seldom properly measured in Federal water resources planning. Very often weights are omitted altogether, leaving the difficult task of judging weights to be performed intuitively by the decision maker. (One thing this chapter should make clear is just how great a burden this places on the decision maker.)

One common erroneous practice is to ask for judgments of the relative importance of such things as "irrigation water" and "habitat quality". This is no more meaningful than asking, Which is more valuable, time or money? One can not compare *dimensions*; one can compare only *differences* on dimensions. While it is not meaningful to ask for a comparison of time and money in the abstract, however, it can be meaningful to ask whether an hour or a dollar is more valuable. Similarly, the kind of question that must be asked in commensurating variables in water planning decisions is: *How much* of a gain in acre-feet of irrigation water would be necessary to just offset in value a loss of *so many miles* of riparian habitat?

Another common erroneous practice is to present ordinal scales for judgment of relative importance. Again, one can compare only differences. Ordinal scales do not represent differences; interval scales are required.

Another common erroneous practice is to measure weights, themselves, on an ordinal scale, respondents being asked simply to rank order the dimensions in terms of importance. Not only an ordinal scale, but even an interval scale is inadequate for the measurement of weights, as the following example shows.

	A	B	
	.60	.40	
Plan I	10	2	.60(10) + .40(2) = 6.8
Plan II	9	4	.60(9) + .40(4) = 7.0 <--

The whole numbers in columns A and B are the scale values of Plan I and Plan II on dimensions A and B, and the decimal fractions at the top of each column are the importance weights for these dimensions. These weights indicate that a unit difference on dimension A is more important (to be precise, half again as important) as a unit difference on dimension B. The calculations on the right take this into account by multiplying the scale values on each dimension by the weight for that dimension to transform them to a common scale, or commensurate them. The commensurated scale values are then added to yield a total for each plan. In this manner, Plan II is shown to be superior to Plan I.

If the weights are measured on anything less than a ratio scale, the zero point will be arbitrary. Because no information will have been obtained about where the zero should really be, one is free to change it, by adding a constant to all the weights or subtracting a constamt from them. Below, a constant of .30 has been subtracted from both weights to show the effect such transformations can have on the overall evaluation of the alternatives.

	A	B	
	.30	.10	
Plan I	10	2	.3(10) + .1(2) = 3.2 <--
Plan II	9	4	.3(9) + .1(4) = 3.1

The final ordering of the alternatives has been reversed by this transformation; adding or subtracting a constant has changed the effect of the weights. A scale that permits such transformations is therefore not suitable for measuring weights; only a scale that prohibits such transformations, a scale with a fixed zero, will do (Hobbes, 1979, p. 126). A ratio scale is such a scale.

Judgment Methods

Two methods will be described for measuring weights: the *point-allocation method* (Metfessel, 1949; Comrey, 1950) and the *tradeoff method* (MacCrimmon & Siu, 1974; Fishburn, 1967). Either should produce satisfactory judgments on a ratio scale. The use of both as checks on one another, if time permits, should produce even better judgments.

While the point-allocation method asks the respondent to produce numerical judgments, the tradeoff method asks for choices. Because a potential difficulty with judgment-based methods, it will be recalled, is lack of realism, the tradeoff method would seem to be preferable in this regard: people in everyday life more commonly choose things than attach numbers to them.

If straight-line approximation to function forms was used to obtain scale values, a warm up will be necessary before obtaining weight judgments. (See pp. 36-40 for a discussion of the warm-up procedure and of the importance of providing realistic stimuli and bias-correcting prompts for the recall of relevant experiences and thoughts.)

The first step in obtaining importance weights by either the point-allocation or the tradeoff method is to make clear to the respondent that the weights are to reflect the relative importance of moving from the least to the most favorable value on each dimension. Note that what are judged are *differences*, not abstract dimensions. A common erroneous practice, as has been pointed out, is to ask for judgments of the relative importance of dimensions without specifying changes along these dimensions. Note also that what is judged is the relative importance of changes on *impact dimensions* (represented by the horizontal axes of the function forms), not value dimensions (represented by the vertical axes). The particular change on the impact dimension that is presented, however, is based on value judgments; it is the change from the least to the most valued impact. Sometimes the difference between the least and most valued impacts will correspond to the difference between the lowest and highest objective values, but often it will not.

The second step is to have the respondent rank order the dimensions in terms of the relative importance of these full-range changes.

> *I*: Now, what I would like you to do is to rank order the dimensions in terms of importance. Let's take income and population as an example, so I can show you how this should be done. The worst and best incomes were $50,000 and $200,000, and the worst and best populations were 1000 and 2000. What I need to know is whether you'd rather go from an income of $50,000 to one of $200,000 or from a population of 1000 to one of 2000.
>
> *R*: That's easy! I'll take the money.
>
> *I*: Fine. Now, I want you to do this for each dimension. For each dimension, consider the importance to you of going from the position you value least to the one you value most, and rank order the dimensions on this basis. It should help to look at the graphs to remind you what your highest and lowest values were. It should also help to move the graphs around and arrange them in order of importance. Tell me what you're thinking as you go through this process, so I'll know why

you feel the way you do about these dimensions.

It is the third step that differs for the point-allocation and tradeoff methods. In the point-allocation method, the respondent is asked simply to divide 100 points among the dimensions in proportion to their relative importances. To make the situation more realistic, the respondent might be asked to imagine having these points to "spend" on the dimensions. Putting all 100 points on one dimension would "purchase" a full-range change on that dimension, from the least to the most desired level, but no change on any other dimension. Putting 50 points on each of two dimensions would "purchase" a half-range change on each of these dimensions, but no change on any other dimension. And so forth. It must be kept in mind that "full-range", "half-range", etc. refer, in this case, to the range on the value dimension (the vertical axis on the graph), not the range on the objective dimension (the horizontal axis on the graph). This method is similar to the method of ratio estimation employed in the measurement of scale values. The principal difference is that, here, the assignment of numbers simultaneously represents several judgments. Checks for consistency should be performed, as discussed below.

Because the point-allocation method, unlike the tradeoff method, requires the respondent to produce judgments on a scale with many values, the error of central tendency becomes a problem (Guilford, 1954). In this case, the error of central tendency would be expected to result in weight judgments that are more nearly equal than they should be (Fisher, 1977). It is not clear how to modify the point-allocation method so as to correct for this error. Round number bias and memory effects are also likely to be present. These errors could be avoided by having the respondent assign line lengths, instead of points, to the various dimensions (see p. 47).

In the tradeoff method, the next step is to ask how much of a change on one dimension is equal in value to a change across the full subjective range on another dimension. Usually, the analyst closes in on the change that is equal in value by asking the respondent for a change that is clearly greater in value and one that is clearly less in value, then gradually adjusts these values towards one another, having the respondent simply choose one interval or another, until the indifference point is reached.

> *I*: You've said that a change from $50,000 to $200,000 in income would be worth more to you than a change from 1000 to 2000 in population. [See Figures 5.2 and 5.3.] What change from, say, your present income of $75,000 would be worth *clearly less* than an increase in population from 1000 to 2000?
>
> *R*: Certainly, a change from $75,000 to $76,000 would be worth less.
>
> *I*: Then somewhere between these two changes on the income dimension, $75,000 to $76,000 and $50,000 to $200,000, we should be able to find a change that is about equal in value to the change in population from 1000 to 2000. That's what we're looking for. How about a change from your current

income of $75,000 to one of $100,000?

R: I'll take the money. But that's getting close.

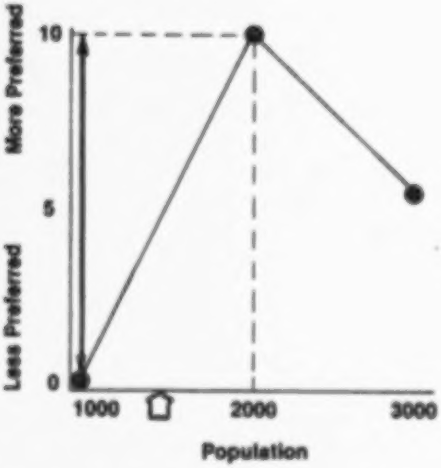

Figure 5.2. Full Value Range on Population Dimension

I: $75,000 to $90,000?

R: That'd be a toss-up. I wouldn't know whether to take the increase in income or the increase in population.

We now have enough information to calculate weights. $75,000 and $90,000 are at 3 and 5 on the value dimension, respectively. The difference, 2, is then equal to the difference on the value dimension between a population of 1000 and one of 2000, 10 minus 0, or 10. Thus, 2 units on the value scale for income are equal to 10 units on the value scale for population; each income unit is 5 times as important as a population unit. As long as the weights assigned to these two dimensions are in this ratio (5 for income and 1 for population, .25 for income and .05 for population, etc.), multiplying the scale values on each by its weight will transform them to a common scale of commensuration.

Notice that this is the same method of judging whether two intervals are or are not equal that was employed in measuring scale values, the method of bisection. The only difference here is that the intervals are from different dimensions, instead of from the same dimension. As was pointed out earlier, this method, because of its simplicity, should be less subject to error, particularly context effects, than other methods (Torgerson, 1958, pp. 56, 103, 117ff; see also Guilford, 1954, pp. 312ff; Parducci, 1963, 1965, 1968).

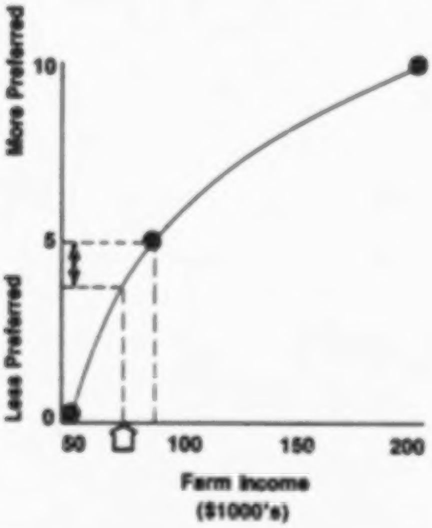

Figure 5.3. Equivalent Value Range on Income Dimension

(*Technical Note*: The question might arise as to why the same judgment method, bisection, yields an interval scale when applied to scale values but a ratio scale when applied to weights. The answer is that it yields an interval scale in both cases. The difference, however, is that in the former case it is an interval scale of scale values (V), while in the latter it is an interval scale of commensurated scale values, which are products of scale values and weights (WV). Ratios among weights, and hence a ratio scale of weights, are obtained by dividing commensurated intervals on different scales (e.g., $W1V1 = W2V2$) by one another ($V1/V2 = W2/W1$). For a related discussion, see the technical note on p. 58.)

The same precautions about order effects and aquiescence and evasiveness response sets discussed in connection with measuring scale values (pp. 43-47) are relevant here. One should adjust in from both sides of the indifference point, and one should use forced-choice questions that do not involve "yes", "no", or "don't know" alternatives.

One approach to obtaining tradeoff judgments of weights is to trade off all dimensions against a common tradeoff dimension and then to make other comparisons as consistency checks. Since the function form for gains is not likely to be the same as the function form for losses (Kahneman & Tversky, 1979), it is advisable, where possible, to trade the other dimensions into just gains or just losses with respect to present conditions.

If time permits, *consistency checks* should be made. Consistency checks are an excellent way to correct for a variety of errors at once. If dimensions A, B, C, and D have been assigned weights of .10, .20, .30, and .40 by trading B, C, and D off against A, the following consistency checks can be performed: Is C half again as important as B? Is D twice as important as B? Is D one-third again as important as C? Performing consistency checks is a kind of "triangulation", or use of different methods for converging on a more valid judgment, and is strongly recommended.

In weight judgments, as in scale value judgments, reasons should be obtained for judgments as a check on the respondents' understanding of the instructions and the meaningfulness of their judgments. Apt expressions of reasons for judgments ("quotable quotes") should be recorded for use in the presentation of the results.

Measurement Error

The earlier discussion (pp. 47-49) of kinds of error, sources of error, and ways to reduce error is as applicable to the judgment of weights as to the judgment of scale values. A recapitulation might be helpful. The earlier discussion was organized in terms of kinds of error: constant and random. This discussion will be organized in terms of sources of error. Errors in judgment can arise in the selection of stimuli, the presentation of stimuli, and selection of response mode.

Selection of stimuli. The meaningfulness of the stimuli selected for judgment affects the relevance of the judgments to real-life concerns. The stimuli should be ones with which the respondent is familiar and with which he/she can easily associate relevant experiences and thoughts.

The range of stimuli selected can affect the scale value judgments in two ways. First, the tendency to adjust the range of the response scale to the range of the stimulus scale (Parducci, 1963, 1965, 1968) will tend to result in judgments that are at the center of the range of bracketing stimuli. Rather than presenting bracketing stimuli to the respondents, the interviewer could ask the respondents, themselves, to suggest stimuli that are clearly high and clearly low. Usually, however, the appropriate range will have been decided by the technical analysis of potential impacts.

Second, the range of stimuli presented on a dimension can also affect the weight judgments, possibly by calling greater attention to dimensions with greater ranges, though this phenomenon is not yet well understood (Levin, Kim, & Corry, 1979; Gabrielli & von Winterfeldt, 1979). Even if the range of impact on a dimension is expected to be slight, a range should be presented for judgment that is representative of the variation normally experienced or thought about.

Finally, the interviewer and the interview situation are stimuli, themselves (Webb, Campbell, Schwartz, & Sechrest, 1966, pp. 12-23). The greater the differences between the interviewer and the respondent on such variables as race, social class, sex, and age, the less likely the respondent's behavior is to be representative of his/her normal behavior. Where differentially impacted publics differ on such variables, interviewers should be matched to respondents. The interview situation should be made as natural and comfortable as possible, and the interviewer should "get acquainted" with the respondent before beginning the interview. Finally, because the interviewer will become more practiced (and also, perhaps, more bored) with experience, the order in which different interest groups are interviewed should be randomized or counterbalanced, at least informally.

Presentation of stimuli. The way in which the stimuli are presented also affects their meaningfulness and the relevance of the judgments to real-life concerns. It is important to allow time for associating relevant experiences and thoughts to the stimuli and to encourage such association by means of conversation. It is also important to provide prompts that tend to counter the tendency to recall only associations that are pleasant, confirming, recent, or frequent (see pp. 36-40).

The order in which the stimuli are presented can also affect judgment. All the dimensions to be judged should be introduced before judgments are obtained on any dimension. Both ascending and descending approaches to indifference points should be employed, and the order of the dimensions being measured for weights should be varied (see p. 47).

Obtaining judgments on the dimensions separately, rather than in the context of multidimensional outcomes, avoids the halo effect (see p. 30).

Selection of response mode. The response mode should not permit avoidance behavior by allowing the respondent simply to agree with a suggested value or to say "don't know" or "no difference" (see pp. 43).

If possible, the response mode should not be a scale with many values, because the respondent will be more inclined to use values near the center of the scale than ones toward the extremes. If such a scale must be used, it should be graphic, rather than numeric, to avoid round number and memory biases (see p. 47).

(*Technical Note*: While sensitivity analysis is equally applicable for evaluating scale value judgments and weight judgments, it is important to point out that the correlation coefficient (specifically, the Pearson product-moment correlation coefficient) is directly applicable only to the evaluation of scale value judgments. What the correlation coefficient measures is degree of linear relationship. If one variable is a perfect linear function of another, the correlation between the two will be a perfect 1.00. Addition or subtraction of a constant or multiplication or division by a constant has no effect on the correlation coefficient. The correlation coefficient measures only the reliability or validity of the intervals; it thus does not discriminate between interval and ratio scales.

(Because ratio scales have a fixed zero in addition to a fixed unit, a measure is required that is sensitive to errors in the location of the zero. A simple way to make the correlation coefficient sensitive to such errors is to multiply the two estimates of the weights to be compared by the same scale values and compute a correlation coefficient on the products. Only if the two weight estimates do not differ or differ only by a multiplicative constant, that is, only if they have been measured on the same ratio scale, will this correlation coefficient be 1.00. Addition or subtraction of a constant, as well as error in the measurement of the intervals, will then lead to departure from a correlation coefficient of 1.00. For a related discussion, see the technical note on p. 55.)

This chapter has shown how to get from the uncommensurated values (V) of Chapter 4 to values commensurated across dimensions (V^*). The next chapter shows how to get from these partially commensurated values to values fully commensurated across both dimensions and publics (V^{**}).

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Chapter 6: COMMENSURATION and CHOICE

Full commensuration is achieved in two cascaded steps: (a) across dimensions within each public, and (b) across publics. (For those who have skipped directly to this point, the concept of commensuration is introduced in the Fable, pp. xi-xii and on pp. 1-11.) Actually, rational decision making sometimes involves tradeoffs and requires commensuration and sometimes does not. The procedure recommended here distinguishes between tradeoffs within publics and tradeoffs across publics. Commensuration within publics is carried out routinely (by judgment-based and/or market-based methods), but the more hazardous step of commensurating across publics is taken only in the event that tradeoffs across publics cannot be avoided.

The fundamental problem in commensurating across persons, whether within or across publics, is what is called *interpersonal comparability*, the comparability from one person or public to another of units on subjective scales. The kind of question at issue is, "If one person rates an impact as a 5 and another person rates the same impact as a 6, is the impact really valued more highly by the second person?" The problem of interpersonal comparability arises whenever a gain for one person or group of persons entails a loss for another person or group of persons, and a judgment must be made as to whether the gain for some is sufficiently great to justify the loss for others.

The assumption is made here that the problem of interpersonal comparability is not so great within publics as across publics. It would seem relatively safe to assume, for example, that farmers raising the same crops in the same area place much the same value on irrigation. Consider a project that would disturb the land of a few farmers but provide water to many. If the few whose land would be disturbed judge the negative effects of the disturbance to be twice as important as the positive effects of the benefits from the additional water, it might be reasonably safe to conclude that the values of the project for each farmer whose land would be disturbed would be 1 - 2 = -1 and that the value for each farmer whose land would not be disturbed would be 1 - 0 = +1. Because of the homogeneity of experiences and interests within this public, it would seem reasonably safe to treat the 1's for its various members as comparable in magnitude, that is, to assume that the unadjusted numbers are directly comparable across persons.

Where interpersonal comparability becomes more difficult is in commensurating across publics. If, for example, a project would benefit the farmers in an area by providing an increased supply of water for irrigation but would at the same time flood the sacred lands of an Indian tribe, the question would be whether the gain for the farmers is greater or less than the loss for the Indians. Virtually any assumptions about, say, the relative importance of +1's and -1's for publics as different as farmers and Indians (or even farmers and community business people, community business people and boaters, boaters and environmentalists, etc.) are open to challenge.

A general principle in aggregation is to perform the less important aggregations first and the more important ones last. In this way, the serious problems remain exposed to view for as long as possible and are not buried under layers of calculations. It is in line with this principle that it is recommended that commensuration be accomplished in two cascaded steps: first within publics, then across publics. It is worth repeating that, while both market-based and judgment-based methods are available for the first step, commensuration within publics, only judgment-based methods are available for the second step, commensuration across publics.

The complete procedure is (a) to commensurate within publics; (b) to seek dominance across publics; and, if a single undominated alternative can not be achieved, then (c) to commensurate across publics.

Commensuration Within Publics

The place of commensuration within publics in the context of public planning decisions is shown in Figure 6.1:

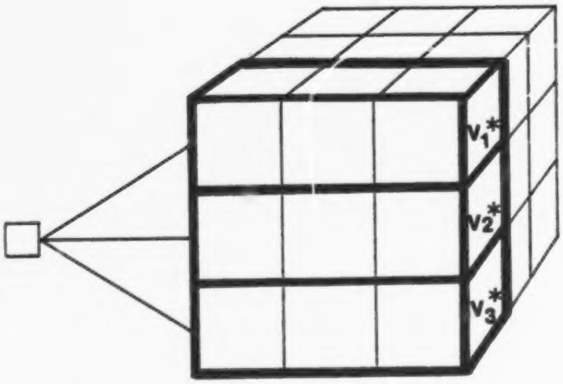

Figure 6.1. Commensurating Within a Public

At this point, it is necessary to introduce some terminology. The following terms and symbols will be used throughout this chapter:

Objective Impact	$Oijk$
Non-Commensurated Value	$Vijk$
Partially Commensurated Value	$V*ijk$
Fully Commensurated Value	$V**ijk$
Social Value	SVi
Dimension Weight	Wjk
Public Weight	Nj

The subscripts are to be read as follows:

alternative i
public j
dimension k

Commensuration within a public can be accomplished across dimensions for each outcome by means of the following equation:

$$V^{*}ij. = Wj1Vij1 + Wj2Vij2 + \ldots + WjkVijk$$

$V^{*}ij.$ is the Partially Commensurated Value of public j for alternative i. The dot in place of the dimensions subscript indicates aggregation across dimensions. What the equation says is that, in order to obtain an overall value for a given alternative (for a given public), one multiplies the value of the alternative on each dimension by the weight for that dimension and than sums the products.

Commensuration within a public should be carried out so as to yield two different kinds of information. One kind of information is the average evaluation of each alternative *on each dimension* ($V^{*}ijk$): for example, the value of the future with and the future without the project in terms of the local economy; the value of the future with and without in terms of the natural environment; and so forth. This information can help in coming up with mitigation measures to be added to alternative plans.

The other kind of information is the average evaluation by the public of each alternative *across dimensions* ($V^{*}ij.$): the overall value of the future with and the future without the project. This is the information that will form the basis of the analysis across publics that will guide the selection of a recommended plan. While the second kind of information indicates which alternative is preferred by the public in question, the first kind indicates why it is preferred. It is important that this information be broken down by publics, since the *Principles & Standards* (1973, p. 108) specifies that "For purposes of accounting, the distribution of beneficial and adverse effects will be shown to whomsoever they accrue."

The first kind of information can be obtained as follows. For each dimension, each respondent has produced a function form judgment, much like the one in the Figure 6.2. In order to read values from a function form, one locates on the horizontal axis the projected impact (say, $90,000) for each of the various alternatives; draws a vertical line from this point to the function, or curve; and draws a horizontal line from this intersection to the vertical axis, where the value judgment (here, 5) is read off. The respondent's value ($Vijk$) is then multiplied by his/her dimension weight (Wjk) to transform it to a scale value on a common dimension of commensuration ($V^{*}ijk$), and these products are averaged across respondents for each dimension and each alternative. This will yield an average value for each alternative on each dimension for the public in question.

In order to obtain the second kind of information, these average values on each dimension can simply be summed for each alternative, to yield a single value for that alternative, $V^{*}ij.$, commensurated across dimensions and individuals within a public.

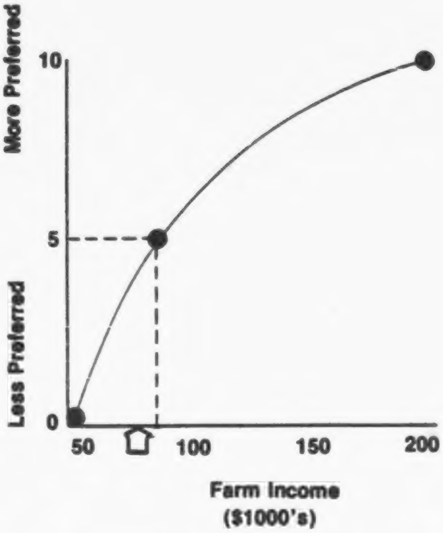

Figure 6.2. Reading a Value from a Function Form

(*Technical Note*: This is equivalent to performing the following operation for each respondent:

$$V*ij. = Wj1Vij1 + Wj2Vij2 + \ldots + WjkVijk$$

and then averaging across respondents. While the indicated procedure is more efficient computationally (because it makes use of the average values on each dimension already computed), this equation should make clearer the logic of a weighted sum that underlies the calculations. Though there are a variety of more complex rules than addition for combining values on dimensions to yield an overall value (e.g., Keeney & Raiffa, 1976; Easton, 1973), a simple weighted sum appears to capture human value judgments satisfactorily (Dawes & Corrigan, 1974; Goldberg, 1970; Yntema & Torgerson, 1961).)

Overall value, $V*ij.$, thus calculated, will be on an interval scale; however, this scale can not be generalized across publics.

Across-Publics Analyses: dominance and commensuration

The place of across-publics analyses in the context of public planning decisions is shown in Figure 6.3: The following equation shows the final step in determining an overall Social Value (SVi) for each alternative, commensurated across both dimensions and publics and weighted for population size. (The method for getting from Partially Commensurated Values (V^*) to Fully Commensurated Values (V^{**}) will be described later.)

$$SVi = N1V^{**}i1 + N2V^{**}i2 + \ldots + NjV^{**}ij$$

SVi is the weighted, Fully Commensurated Value of alternative i, across dimensions and publics. What this equation says is that Social Value is arrived at by multiplying each public's Public Weight by its Fully Commensurated Value for alternative i and then summing these products across publics. The terms of the equation provide a conceptual framework for discussions of both the dominance analysis approach and the tradeoff analysis approach to dealing with value differences across publics.

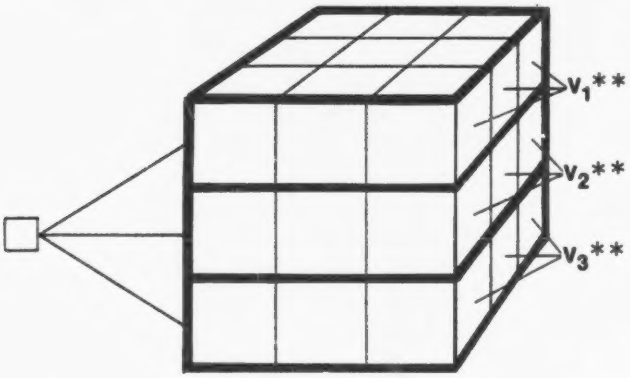

Figure 6.3. Commensurating Across Publics

Dominance analysis. Dominance analysis makes use of only the ordinal properties of measures of value. Because interval properties do not affect this analysis, the problem of commensurating units does not arise. The Partially Commensurated Values (V^*) for each public are sufficient for dominance analysis.

The search for dominated alternatives should precede any attempt to commensurate across publics (Cohon, 1978; Dorfman, 1972; Dorfman, Jacoby, & Thomas, 1972; Keeney & Raiffa, 1976; Pareto, 1927; Schaumburg, 1973). A dominated alternative, it will be recalled (see pp. 31), is one for which there is at least one other alternative that is superior on at least one dimension and inferior on none. *When it is the Partially Commensurated Values (V^*) of the various publics that are taken as the dimensions, a dominated alternative is one for* *which there is at least one other alternative (a) that is preferred by at least one public, and (b) to which the original alternative is preferred by no public.* In other words, one alternative dominates another if it is better for some publics and worse for none. No way of weighting the publics, either in commensurating to a Fully Commensurated Value (V^{**}) scale or in applying Public Weights, can possibly lead to preference for a dominated alternative.

If the number of publics and plans is small, dominance analysis can be carried out simply by inspection. For more complex cases, efficient numerical procedures are available (e.g., Kung, 1974), and the Evaluation and Sensitivity Analysis Program (ESAP; Mumpower & Bollacker, 1980), available to the Army Corps of Engineers and the Bureau of Reclamation, has a capability for identifying dominated alternatives.

If more than one alternative remains after the elimination of dominated alternatives, consideration should be given to trying to create an alternative that will dominate all others by adding *mitigation measures* to plans that have survived the initial screening. *The great virtue of mitigation measures is that they can produce changes in the evaluation of alternatives within a public that lead to a different ordering of the alternatives by that public and thus to a single dominated alternative across publics.*

Assume, for example, that Plan I is preferred to Plan II by all publics but one. Determining whether the combined benefits to the several publics outweigh the cost to the one public would require a measure of value that is comparable across publics. However, if a mitigation measure can be found that will change this one public's ordering of the alternatives at least to indifference, without at the same time reversing any of the other publics' orderings, Plan I will dominate Plan II, and Plan I can then be selected without having to make across-public comparisons (see Arrow, 1963, p. 34). *This potential value of mitigation measures can not be stressed too greatly.*

The dimension-by-dimension evaluation of alternatives should aid the process of coming up with mitigation measures. It can indicate what a given public would need in order to change its ranking of the alternatives; and, should budget constraints require one public to give up something in order to permit compensation of another, it can also indicate what that public could give up without changing its ranking.

Tradeoff analysis. Tradeoff analysis makes use of both ordinal and interval properties of measures of value. Commensuration of units is the central consideration in tradeoff analysis. The problem is to transform the Partially Commensurated Values (V^{*}) of the separate publics into a common Fully Commensurated Value (V^{**}) scale.

If, as will often be the case, elimination of dominated alternatives and addition of mitigation measures fails to narrow the alternatives down to a single best alternative, the difficult problem of trading off one public's loss for another's gain must be faced. It is at this point that weights become critical (Hobbes, 1979, pp. 125-126; McClelland, 1978). One must proceed with caution in commensurating across publics, for this step would seem to require greater judgment and political wisdom than any other step in the entire commensuration process.

The current practice for commensurating across publics is generally more political than analytic. The judgments of appointed and elected officials and the processes of debate, negotiation, and compromise are currently used to deal with this problem (Lord, Deane, & Waterstone, 1979). As yet, no satisfactory analytic substitute has been found for these processes (see Peterson & Gemmell, 1977). However, *analytic aids to inference, judgment, and communication are available that should be able to improve this process and the quality of the resulting decisions*. The recommended method shows how a number of such aids can be made use of.

The principal recommended aid is to express the impacts to the various publics in terms of a single *tradeoff dimension*. Only a single dimension of impact, such as income, property taxes, or water rates, needs to be considered in making comparisons across publics, since each public will have already judged the relative importance of the other dimensions in comparison with it. (Considerations involved in selecting a tradeoff dimension are discussed on p. 27. However, it may be desirable for especially difficult and important judgments to use *two or more* tradeoff dimensions as checks on one another and thus to perform a sensitivity analysis on the tradeoff dimensions. An example should clarify the use of a tradeoff dimension for commensurating across publics.

Consider further the example of a project that would provide irrigation water to farmers but that would flood a place that a local Indian tribe considers sacred. Note that these publics are impacted on different dimensions. Note also that the concepts of irrigation and of a sacred place may not have anything like the same meanings to the farmers and the Indians. Note finally that any realistic situation is likely to be more complex than this example in that the farmers and the Indians would each be likely to be impacted on multiple dimensions. While this greater complexity would make commensuration judgments without the recommended procedure considerably more difficult, it would have *no effect whatsoever* on the difficulty of commensuration judgments using the recommended procedure.

Assume that the Indians have said that a $200 loss in annual income would be equal in value to the loss of the sacred place (or, if they had made judgments directly in terms of the income tradeoff dimension, that they would be willing to pay $200 a year to preserve the sacred place) and that the farmers have said that a $2000 loss in annual income would be equal in value to the loss of the irrigation water (or, if they had made judgments directly in terms of the income tradeoff dimension, that they would be willing to pay $2000 a year to obtain the irrigation water). If a decision maker judges that a $200 reduction in the Indians' income would be a more severe impact than a $2000 reduction in the farmers' income, the implication is that the sacred place is more important to the Indians than the irrigation water is to the farmers. Otherwise, the implication is that the irrigation water is more important to the farmers than the sacred place is to the Indians. While it is admittedly difficult to make judgments of this sort, it should be *less difficult* to make them with respect to a single dimension than with respect to a number of dimensions simultaneously, as is the current practice.

There has been considerable discussion in the literature of the problem of commensurating across individuals. Surely, the most influential statement on this topic in recent years has been Arrow's impossibility theorem ("Arrow's paradox"; Arrow, 1951, 1963):

> If we exclude the possibility of interpersonal comparisons of utility, then the only methods of passing from individual tastes to social preferences which will be satisfactory and which will be defined for a wide range of sets of individual orderings are either imposed or dictatorial.

Though Arrow concerned himself primarily with the statement in this form, many (e.g., Goodman & Markowitz, 1952; Hildreth, 1953 see Luce & Raiffa, 1957, Ch. 14) have been more concerned with its logical converse: Any method of passing from individual preferences to social preferences which is satisfactory, which will be defined for a wide range of sets of individual orderings, and which is neither imposed nor dictatorial, *must* admit the possibility of interpersonal comparisons of utility. In other words, in order for a method of aggregating the values of different publics to be at all democratic, interpersonal comparisons of utility *must* be made.

Dahl (1956, p. 90) argues along somewhat different lines to the same conclusion:

> What if the minority prefers its alternative much more passionately than the majority prefers a contrary alternative? Does the majority principle still make sense?
>
> This is the problem of intensity. And, as one can readily see, intensity is almost a modern psychological version of natural rights. For, much as Madison believed that government should be constructed so as to prevent majorities from invading the natural rights of minorities, so a modern Madison might argue that government should be designed to inhibit a relatively apathetic majority from cramming its policy down the throats of a relatively intense minority.

Not only theory, but also political practice, has refused to be content with simple voting procedures. In political practice, voting is commonly supplemented by the mechanism of "logrolling", in which a congressman who feels strongly about one bill and indifferent about another trades his/her vote on the second for a vote on the first from a congressman who feels more strongly about the second. In this way, the relative strengths of preference of those exchanging votes are taken into account by a "vote market" (Flood, 1978) (which, incidentally, has most of the same problems as other markets as a basis for determining public values; see pp. 4-8).

It has been argued (e.g., Harsanyi, 1955, 1977, 1979; and even Arrow, 1978) that individuals are able empathetically to make judgments with a useful degree of validity about the utility of outcomes for other individuals. The argument is that this can be done on the basis of a knowledge of the others' actual choices, the others' expressions of satisfaction and dissatisfaction, and the various factors that relate to satisfaction and dissatisfaction.

> ...Any interpersonal utility comparison is based on what I will call the *similarity postulate*, to be defined as the assumption that, once proper allowances have been made for the empirically given differences in taste, education, etc., between me and another person, then it is reasonable for me to assume that our basic psychological reactions to any given alternative will be otherwise much the same.... Its intuitive justification is that, if two individuals show exactly identical behavior--or, if they show different behavior but these differences in their observable behavior have been properly allowed for--then it will be a completely arbitrary and unwarranted assumption to postulate some further hidden and unobservable differences in their psychological feelings.... We use this similarity postulate not only in making interpersonal utility comparisons but also in assigning other people human feelings and conscious experiences at all (Harzanyi, 1977, pp. 638-638, 640).

The belief in the possibility of interpersonal comparisons of utility is hardly new. In the *Old Testament* (II Samuel 12: 1-4), it is stated that: "In law we assume that one man's life has the same value to him as another's does to the other." In the *New Testament*, the admonition to "Do unto others as you would have others do unto you" seems to be based on the assumption that the values of different individuals are essentially alike. (This admonition, incidentally, appears to have a close counterpart in all cultures.)

Granting that commensuration judgments can be made, how might they best be made? Recall that the value of an alternative, commensurated across publics, can be expressed as follows:

$$SVi = N1V^{**}i1 + N2V^{**}i2 + \ldots + NjV^{**}ij$$

There are two topics be discussed, the determination of the Public Weights (*Nj*) and the transformation of Partially Commensurated Values (*V**) into Fully Commensurated Values (*V***).

Nj is the Public Weight for Public *j*. It is based on the size of that public. Weighting by population size is necessary to make the analysis conform to the one-person-one-vote principle of democratic voting and to increase the degree to which the final ordering of alternatives accurately reflects the promise each holds for contributing to "the greatest happiness for the greatest numbers" (Hutchinson, 1725; in Rawls, 1971, p. 22).

The size of a public can be estimated on the basis of secondary data obtained from public records or from primary data obtained from a random sample of the general public in the area. Once the entire impacted public has been partitioned and its total population apportioned among the resulting publics ($n1$, $n2$, $n3$, etc.), Public Weights (Nj) are computed as follows:

$$
\begin{aligned}
N1 &= n1/(n1 + n2 + \dots + nj)\\
N2 &= n2/(n1 + n2 + \dots + nj)\\
&\vdots\\
Nj &= nj/(n1 + n2 + \dots + nj)
\end{aligned}
$$

These weights will be decimal fractions that sum to 1.00. It is important that division by the total be performed so that the resulting weights will be relative. Otherwise, population increases will automatically and inevitably be counted as utility increases (Rawls, 1971, p 162). This would be entirely inappropriate. (The appropriate point at which to introduce evaluations of any impacts on population is when function forms and dimension weights are judged.)

What we now have is the V^*'s and N's. Multiplying the V^*'s by the N's, however, would not be that much different from simply taking a vote. The process to this point has not yet distinguished between Dahl's "apathetic majority" and "intense minority". It is also open to all the problems pointed out by Arrow. To avoid the "tyranny of an apathetic majority" and Arrow's paradox, the decision maker must attempt to arrive at an appropriate transformation of partially commensurated V^* values for the separate publics into values on a fully commensurated common V^{**} scale. This is the second step in the cascade.

It should be made very clear that this transformation is to reflect the importance of the *numbers* used by equally valued publics, not the importance of the *publics*. To give, say, farmers twice the weight of community business people would not be to say that farmers are any more important than community business people, but simply that a given numerical difference judged by farmers on the tradeoff dimension is twice as important in terms of human value as the same numerical difference judged by community residents. To do otherwise would be to treat some persons as more important than others.

Market-based analyses usually attach equal weight to a dollar for a millionaire and a dollar for a person at the poverty level. Monetary benefits and costs are simply added up. While this is satisfactory for commensurating within a public that is reasonably homogeneous with respect to income, *it amounts to using different scales to measure the benefits and costs to publics that differ appreciably in income.* Specifically, it overweights impacts on the wealthy. No market-based technique to commensurate such scales seems to have been suggested; the judgment of informed decision makers would seem to be required.

The recommended technique simplifies the interpersonal comparisons required for full commensuration by presenting differences on a single tradeoff dimension. To see how this is done, consider an example in which there are two alternative plans and two publics. Let the tradeoff dimension be income. And, to simplify the calculations, let the publics be of the same size, so that *Nj*'s do not have to be employed. Assume the following values for each plan and each public.

Public 1

	Econ	Soc	Env	V^*_{i1}.
	.6	.1	.3	
Plan I	8	5	8	7.7
Plan II	5	6	2	4.2

Public 2

	Econ	Soc	Env	V^*_{i2}.
	.4	.3	.3	
Plan I	4	3	5	4.0
Plan II	7	5	4	5.5

The V^* dimension is not a good dimension for judging tradeoffs across publics, since it is abstract and likely to convey little, if any, real information to the decision maker. Instead, one of the original dimensions, D, should be used.

Perhaps the best tradeoff dimension is the one on which market analyses are based: dollars. There seems to be no scale in terms of which people are so practiced in quantifying values. Also, if market-based analyses have been carried out at the within-publics level, their output will already be in dollars, and this will facilitate comparison. (Note, however, that the output of market-based analyses is most frequently in terms of benefits and costs summed over individuals. The recommended unit of analysis for judgment purposes is the individual; impacts should be quantified in terms of dollar impacts on individuals in order to provide as meaningful a basis for judgment as possible.) Though income, taxes, and water-user's fees are also suitable as tradeoff dimensions, the rest of this discussion will take income as the tradeoff dimension.

In trading off to a common dimension within a public, that public's scale values on the tradeoff dimension are taken as given, and those on the other dimensions are multiplied by appropriate weighting factors to convert them into scale values (*Vijl*) on the tradeoff dimension. The appropriate weighting factor for a dimension is its Dimension Weight divided by the Dimension Weight of the tradeoff dimension. The weighting factor for the tradeoff dimension will, thus, always be 1.0, and the scale values on this dimension will not be altered.

The calculations below commensurate all dimensions in the example in terms of the tradeoff dimension for each public and sum the commensurated impacts across dimensions:

Public 1
Plan I
$(.6/.6)(8) + (.1/.6)(5) + (.3/.6)(8) = 12.8$
Plan II
$(.6/.6)(5) + (.1/.6)(6) + (.3/.6)(2) = 7.0$

Public 2

Plan I
$(.4/.4)(4) + (.3/.4)(3) + (3./.4)(5) = 10.0$
Plan II
$(.4/.4)(7) + (.3/.4)(5) + (.3/.4)(4) = 13.8$

Finally, these impacts on the abstract scale ($Vij1$) are transformed, via the public's function form for income, into dollars ($Dij1$). These transformations are shown below on the function form for each public. (See Figures 6.4 and 6.5.) In terms of dollars, the two plans are evaluated by each public as follows:

	Public 1	Public 2
Plan I	$42,000	$15,000
Plan II	$36,000	$20,000

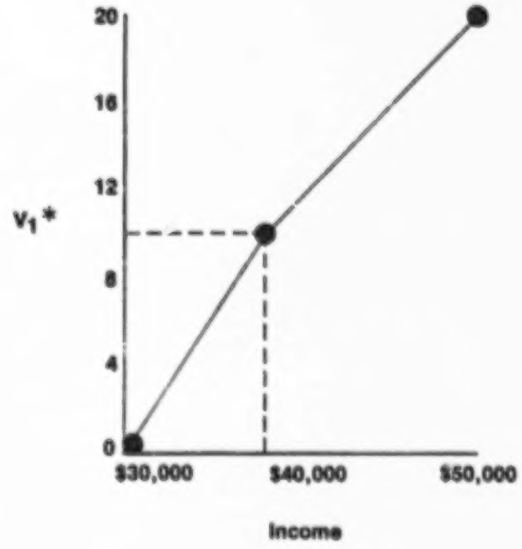

Figure 6.4. Income Function Form for Public 1

On the assumption that an impact that Public 1 is willing to tradeoff for a dollar and an impact that Public 2 is willing to trade off for a dollar have the same human value (and on the assumption of equal Public Weights), the values of the plans are:

Plan I: $42,000 + $15,000 = $57,000
Plan II: $36,000 + $20,000 = $56,000.

On this basis, Plan I would be selected for recommendation.

However, the point of this section is that the decision maker should not assume that the worth of a dollar is the same for all publics. Considered judgments should be made about the relative worths of dollar changes for different publics.

The task left to the decision maker is essentially to specify a function form, or utility curve, for income. It is widely agreed that the utility curve for income is concave downward, exhibiting decreasing marginal utility (an additional dollar is worth less, the more you already have). The following statement by Mishan (1974, p. 80) is prominent among the many that argue for a utility curve that is concave downward: "The guiding maxim I would offer is that it is more important to prevent avoidable suffering [loss in utility] than to create further opportunities for self-indulgence [gain in utility]". (Though there are notable exceptions--for example, persons who become more concerned about money the more money they have--they would seem to be infrequent; and, in any case, the most useful defense of the principle may be not so much as a description of existing values as an ethical principle for public decision making.)

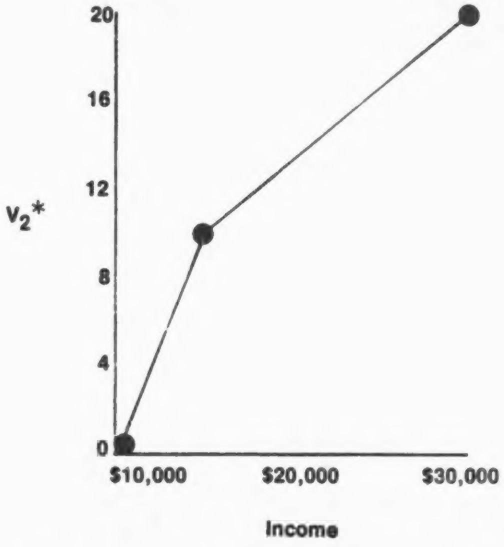

Figure 6.5. Income Function Form for Public 2

While there is agreement on the general shape of the utility curve for income, there is considerable need for judgment in establishing the particular curvature. Once such a function form has been judged, it can be used to transform impacts judged by different publics to common V^{**} values. These values can then be multiplied by the Public Weights and summed across publics.

There are at least three approaches to obtaining judgments from the decision maker about the utility curve for income. The decision maker could simply be presented with the impacted publics, their population sizes, and their tradeoff values for the alternatives and left to make the required judgments intuitively.

At the other extreme, the decision maker could actually judge the required function form for the tradeoff dimension. To do this properly, decision makers would require guidance, either from a judgment and decision analyst or from step-by-step instructions contained in the report.

There is an intermediate possibility, however, that would seem to strike a balance between ease of application and rigor: presenting the decision maker with a *break-even* utility curve. This is the procedure that is recommended. A break-even utility curve can be determined as follows.

1. On the basis of a linear utility curve, identify the preferred alternative and its closest competitor;
2. Identify the inflection point that defines a two-segment utility curve which yields identical V^{**} values for these two alternatives.

An example should help.

Let us continue the example of the two plans and the two publics. The following graph represents income, ranging from $10,000 to $50,000 on the horizontal axis and V^{**}, ranging from 0 to 10, on the vertical axis. The question as to what the relative worth of a dollar is for different publics can be reduced to the question as to what the appropriate function is relating V^{**} to income (and similarly for the unit on any other tradeoff dimension). This assumes, and it would seem reasonably, that the principal variable determining the worth of a dollar is present income. A dollar is worth less, the more money you have to begin with.

Consider two utility functions (see Figure 6.6), one in which the mid-value point on the income dimension is $30,000 and one in which it is $20,000. These are Curves A and B, respectively. (The possibility of defining utility curves in terms of curved-line, rather than straight-line, segments will be considered below.) On Curve A, the income that would have a V^{**} value of 5 is $30,000, and, on Curve B, it is $20,000.

The curve we are interested in will fall somewhere above Curve A. This is because of the fact that it is generally accepted that utility curves should have some downward curvature. Curve A has zero downward curvature, and any curve below it would actually have upward curvature. In terms of Curve A, the values the two publics place on the two plans have the V^{**} values shown in the first column below. (A comouter program, written in BASIC, for computing utilities on the basis of two-segment curves is included in the Appendix.)

UTILITIES for DOLLAR AMOUNTS

Dollar Value	V**(A)	V**(B)
$42,000	8.00	8.67
$36,000	6.50	7.67
$20,000	2.50	5.00
$15,000	1.25	2.50

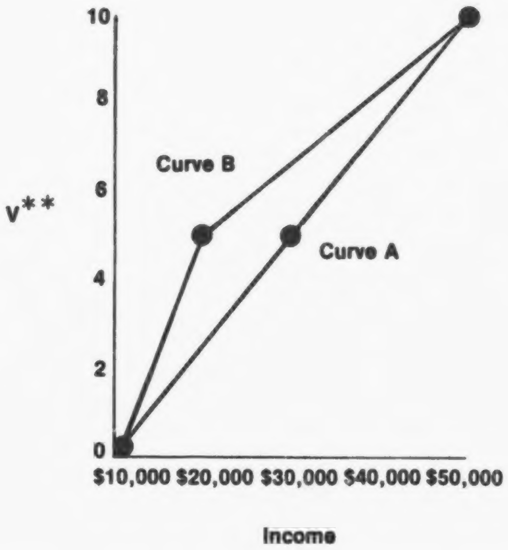

Figure 6.6. Income Function Form Across Publics

Two points should be made about these figures. One is that the dollar values in the first column are not final asset positions. If they were, they should have identical V** values for all publics. They are changes from initial asset positions. The second point is that the figures do not represent simply impacts on income, but all impacts traded into income. That is why they are so high.

The average V** value for each plan (also in terms of Curve A) is as shown in the first of the two tables below:

UTILITIES for PLANS

Mid-value = $30,000

	P1	P2	Mean V**
Plan I	8.00	1.25	4.63 <--
Plan II	6.50	2.50	4.50

Mid-value = $20,000

	P1	P2	Mean V^{**}
Plan I	8.67	2.50	5.59
Plan II	7.67	5.00	6.34 <--

The space above Curve A must now be explored for a break-even curve. A curve with a mid-value of $20,000 would seem worth examining, since it defines that two-segment mid-value utility curve that would put the greatest relative weight on the public that prefers the second alternative. In terms of this curve, Curve B, the values the two publics place on each plan have the V^{**} values shown in the second column in the Utilities for Dollar Amounts table above, and the average V^{**} for each plan is as shown in the second Utilities for Plans Table.

These results can be plotted on the break-even graph in Figure 6.7, where the horizontal axis represents the mid-value point on the income dimension, ranging from a possible low of $10,000 to a possible high of $50,000, and the vertical axis represents the V^{**} values of the various plans, ranging from 0 to 10: The intersection of the line for Plan I and the line for Plan II is where the V^{**} values for these plans are equal. This is the break-even point, and it occurs here at a mid-value of approximately $28,000. Thus, a two-segment utility curve with a low value of $10,000, a high value of $50,000, and a mid-value of $28,000 is the break-even utility curve. Curves less bowed than this will favor Plan I, and curves more bowed will favor Plan II.

The question that is posed to the decision maker is then:

- BREAK-EVEN UTILITY CURVE QUESTION -

> Which would represent a greater change in human terms, an increase in income from $10,000 to $28,000 or an increase in income from $28,000 to $50,000?

If an increase from $28,000 to $50,000 is judged to be greater, the originally preferred plan should be chosen; if an increase from $10,000 to $28,000 is judged to be greater, the originally second-ranked plan should be chosen. To make numbers on the tradeoff dimension less abstract to the decision maker, anchors should be provided that translate income into such meaningful goods as food, housing, and medical services. Such information can be obtained from the Bureau of Labor Statistics. If the tradeoff dimension judged by representatives of the various publics was income, the income level the representatives for each public had in mind when making their judgments should also be presented to the decision maker. Every effort should be made to ensure that the decision maker will give careful thought to this break-even judgment.

Two cautions are in order regarding the search for a break-even utility curve and one regarding its application. First, the discussion so far has been couched in terms of two-segment curves inflected at the mid-value point. This definition includes only curves that fall in the shaded area in Figure 6.8 (assuming also the restriction to utility curves that do not have downward curvature): The shaded area excludes curves such as the one represented by the dashed lines. The reason for preferring to work with a definition of utility curves in terms of mid-value points, of course, is that this presents the simplest judgment task to the decision maker. As the mid-value point approaches the low end of the income range, however, the potential for distortion introduced by this restriction becomes greater. It may not be possible to find a utility curve defined in terms of the mid-value point that will reverse the preference for the two leading plans. In this case, it may be necessary to define a two-segment utility curve in terms of its inflection at a point that is, say, three-fourths, instead of halfway, up the *V*** scale. (The BASIC program in the Appendix for two-segment utility curves will handle two-segment curves inflected at any *V*** value between 0 and 10.)

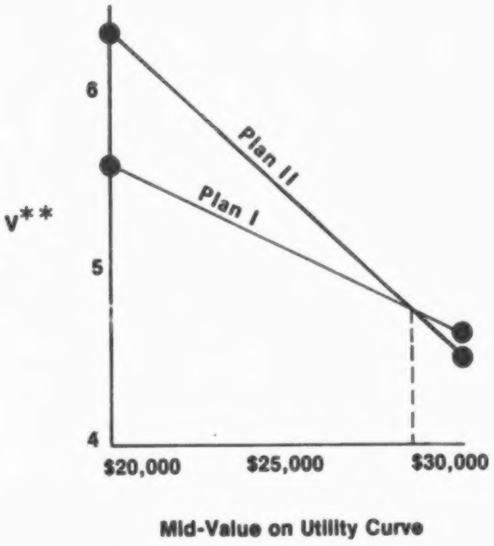

Figure 6.7. Break-Even Graph

The second caution regarding the search for a break-even utility curve is that the *V*** values of the plans will not necessarily vary linearly as a function of the mid-value of the utility curve. In the example, only two sets of *V*** values were computed, corresponding to mid-values of $20,000 and $30,000, and the break-even mid-value was found simply by linear interpolation between these values. As a general rule, however, this simplified approach is not sufficiently cautious. The space should be explored more fully by the computation of *V*** values at a number of strategically spaced mid-value points before making the final linear interpolation to the break-even mid-value. Also, one should compute bracketing values close to the break-even value, so that interpolation will be only over a short distance.

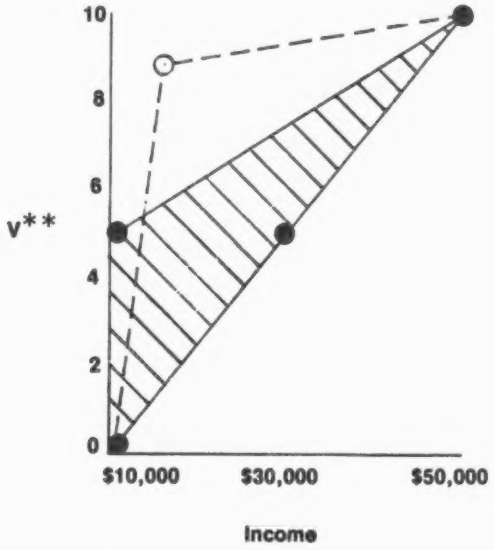

Figure 6.8. Restriction on Utility Curves

The caution regarding the *application* of a break-even utility curve pertains to any public that "straddles" the inflection point, having a substantial number of members with incomes above the inflection point income and a substantial number with incomes below that point. The best procedure in such a case is simply to divide the public into two sub-publics on the basis of income, at the inflection point income. (Such a public should be treated as two sub-publics in the within-publics analysis, as well.)

(*Technical Note*: Stineman's (1980) "well-behaved method of interpolation", which provides a method for generating two-segment utility curves from curved, rather than straight-line, segments, eliminates the sharp inflection point and thus eliminates the "straddling" problem in the most elegant manner.)

Eventually, the recommended method for commensurating across publics could be extended to permit the decision maker to interact with a computer program that would accept ethical principles as constraints on the possible *V*** utility curves. One such constraint, marginal utility that decreases (or at least does not increase) as a function of initial asset position (income level), has been designed into the present procedure. Another possibility is marginal utility that is a constant percentage of initial asset position. (For a discussion of such principles, see Mishan, 1980.)

The recommended method has the following merits:

1. It isolates the essential commensuration questions and presents them in a manner that facilitates meaningful judgments.
2. It is a decision-aiding, not a decision-making, method. It provides information the decision maker needs in order to be able to think seriously about the problem, not simply a recommended alternative that the decision maker is either forced or permitted to accept or reject without serious thought.

Equity and Risk

The decision maker might wish to take two additional factors into account when making judgments about the relative benefits accruing to various publics. One is equity. *Equity* refers not to total value but to the fairness of distribution of value across persons or publics. The achievement and maintenance of equity is viewed as an important function of government. As noted above, the *Principles & Standards* (1973, p. 81) seems to be concerned with distribution, specifying that SWB effects are effects on "the equitable distribution of real income and employment" and "other social opportunities". Though the recommended analysis is based on total value, it provides appropriate input for judgments by decision makers about both total value and equity.

The reason for waiting until this point to introduce the topic of equity is that there is some controversy about the proper method for treating equity. One view (Harsanyi, 1975), and the one to which the author of this paper is inclined, is that the process of commensuration across publics already takes into account the differences in initial asset position and need of the various publics. To do so again would be to double count. Others (Sen, 1973; Rawls, 1971), however, argue that equity must be addressed separately if what we call "rights" are to be respected. The issue is by no means settled.

The second factor that the decision maker may wish to take into account at this point is *risk*. There are two arguments for waiting until this point to take the value of risk into account, rather than assessing and aggregating the public's attitudes toward risk along with their other values. One is that risk assessment is complicated and would be difficult to carry out on large numbers of representatives of the public (see, e.g., Raiffa, 1968; Keeney & Raiffa, 1976; Stokey & Zeckhauser, 1978, p. 252). The other is that the appropriate attitude toward risk may be different for society and for individual members of society (see, e.g., Arrow, 1967; Keeney, 1980; Stokey & Zeckhauser, 1978, p. 252). The value of risk is discussed in the next chapter.

The simplest way to deal with both equity and risk is at an ordinal level, by eliminating dominated alternatives. If all publics are indifferent about two alternatives (so that neither is dominated on this basis) yet one distributes more of its positive impacts to those who are already better off and/or more of its negative impacts to those who are already less well off, this second alternative could be eliminated without having to make interval-scale judgments of equity. Similarly, if all publics are indifferent about two alternatives but one has less certain impacts, this second alternative could be eliminated without having to make interval-scale judgments of risk. If such dominance screening is not possible, the more difficult interval-scale judgments of equity and risk will have to be made. Risk is discussed further in the next chapter.

Chapter 7: UNCERTAINTY, INFORMATION, and UTILITY

Uncertainty exists when there is more than one possible consequence for any alternative; the greater the number of possibilities and the more nearly equal their probabilities, the greater the uncertainty (Attneave, 1959; Garner, 1962). *Information* is that which reduces uncertainty. *Utility* is a measure that takes into account both the value associated with the possible outcomes of an alternative and the value associated with the uncertainty of those outcomes (Brown, Kahr, & Peterson, 1974; Keeney & Raiffa, 1976).

There is virtually always uncertainty about impact projections. Information is virtually never good enough to justify planning in terms of a single future. Flooding deer habitat, for example, might be expected in a particular case to reduce the deer population by anywhere from 5 percent to 15 percent. Increasing the number of people in a community could be seen as increasing the load on community services and thus having a detrimental effect or as providing a stimulus and a tax base for improved services and thus actually having a beneficial effect. Predictions can almost never be made with certainty.

Unless handled properly, uncertainties can lead to poor decision making (Holling, 1980, p. 7; Janis & Mann, 1977). Uncertainties about possible harmful impacts on the environment, for example, have tended to produce two extreme reactions, neither of which is conducive to sound decision making. One extreme is to be paralyzed by these uncertainties and to oppose all development. The other is to avoid thinking about what seem to be imponderables and thus not to take them into account at all in making decisions. The first overweights uncertain impacts; the second underweights them.

Several points need to be made about uncertainty: (a) uncertainty should be reported; (b) the sensitivity of the decision to uncertainty should be examined; and (c) if the decision is sensitive to a particular source of uncertainty, either a plan should be generated that is less sensitive to uncertainty, more information should be obtained before selecting a recommended plan, or the value of uncertainty should be taken into account when selecting a recommended plan.

The Representation of Uncertainty

The most common way to report impacts is to give point estimates: deer population will be reduced by 10 percent, community services will be overburdened by 5 percent. Point estimates hide uncertainty, and this is why technical experts so often feel uncomfortable about making them. It is more appropriate and more responsible to provide range estimates in addition to point estimates: deer population will be reduced by 10 percent +/- 5 percent, community services will be overburdened by 5 percent +/- 15 percent.

Strictly speaking, such range estimates are meaningless unless accompanied by probability figures. Are the ranges such that 90 percent are expected to include the true values and 10 percent to exclude them? Or are they such that 50 percent are expected to include the true values and 50 percent to exclude them? It makes a difference. If one were free to adjust the probabilities, one could report any range whatsoever. Even if a numerical probability is not reported, at least something should be said about how often it is believed that true values will fall outside the reported ranges. Techniques are available for helping experts to make probability judgments (Huber, 1974; Lichtenstein, Fischhoff, & Phillips, 1977; Spetzler & Stael von Holstein, 1975).

Uncertainty requires not only that ranges be reported when making impact projections but also that ranges of potential impact be presented when obtaining value judgments. The use of the method of function-form judgment assures that this will be done.

The Sensitivity of the Decision to Uncertainty

The question addressed by *sensitivity analysis* is whether the ordering of the alternatives is sensitive to a given source of uncertainty. The *Principles & Standards* (1973, p. 12) states that "Plans should be examined to determine their sensitivity to data availability and to alternative assumptions as to future economic, demographic, environmental, and technologic trends."

The following example should help to clarify the meaning of sensitivity analysis. Assume that, on a particular problem, the ratings assigned by various judges to Plan I and Plan II on dimensions A, B, and C cover the ranges shown below:

	A	B	C
Plan I	8-10	7-8	5-10
Plan II	2-3	4-7	5

The midpoints of these ranges and their sums are shown below:

	A	B	C		
Plan I	9.0	7.5	7.5	24.0	<--
Plan II	2.5	5.5	5.0	13.0	

On this basis, Plan I would be preferred to Plan II. However, there is considerable uncertainty about the rating of Plan I on dimension C. This rating ranges from 5 to 10. One way to perform a sensitivity analysis would be to see whether using the figure at the low end of this range would alter the decision. This change and the results are shown below:

	A	B	C		
Plan I	9.0	7.5	5	21.5	<--
Plan II	2.5	5.5	5.0	13.0	

Because Plan I still has a higher total than Plan II, the decision is not sensitive to this particular source of uncertainty.

A more severe sensitivity analysis would be to use the figures at the low ends of all ranges for Plan I and those at the high ends of all ranges for Plan II. These figures are shown below:

	A	B	C		
Plan I	8	7	5	20	<--
Plan II	3	7	5	15	

Because Plan I is still preferred to Plan II, the decision is not sensitive to any of these sources of uncertainty.

Computer programs, such as the Evaluation and Sensitivity Analysis Program (ESAP; Mumpower & Bollacker, 1980), available to the Corps of Engineers and the Bureau of Reclamation, make it easier to perform sensitivity analyses. Unfortunately, they are not yet widely available, and none provides for the second step in the cascade.

If a computer program is not available for performing a sensitivity analysis, it will be necessary to take heuristic shortcuts in order to keep the complexity of the sensitivity analysis from getting out of hand. One heuristic is to examine only those dimensions that seem intuitively likely to be important sources of uncertainty. For a source of uncertainty to be important, not only must the range of potential impacts be large, but the weight placed on that dimension must also be substantial.

Another heuristic is to test categories of impact and to exclude from further consideration variables within categories that do not appear to be critical or near critical. For example, one could look at the values of each public, to find out to which public's values the decision is most sensitive, then perform dimension-by-dimension sensitivity analyses within only the most critical public or publics.

Another heuristic is to examine each of the dimensions selected for sensitivity analysis separately, holding the others constant, and testing the combined impacts of only those dimensions that this test shows to be critical. While it is true that a large number of small impacts could all go the same way and create a large impact, this is unlikely.

In most cases, it will turn out that impacts will have been estimated with all the precision that the decision requires. In such cases, the remaining uncertainty has no relevance for the decision, and any attempt to deal with it further would be a waste of time.

In other cases, it will turn out that the ordering of the alternatives depends critically on where within the estimated range the true impact falls; the decision is sensitive to this source of uncertainty. In such cases, one should give thought to generating a plan that is less sensitive to uncertainty. Generating a plan that would be preferred in any likely future is the same kind of solution as generating a plan that would be preferred by any public. Such solutions are highly desirable, but they require creative thinking--and luck. One general principle in generating such plans is to maintain variability in systems, to keep options open. "...A major function of planning must be to create and preserve options rather than close them..." (Creighton, 1976, p. 8). "The more that variability in partially known systems is retained, the more likely it is that both the natural and management parts of the system will be responsive to the unexpected" (Holling, 1980, p. 19). This is the familiar principle of diversifying one's investments, of not "putting all your eggs in one basket".

If it is not possible to conceive of a plan that is less sensitive to uncertainty, one has two alternatives: (a) to reduce uncertainty by gathering more information before making the decision, or (b) to take uncertainty into account when making the decision.

Information and the Reduction of Uncertainty

The decision to require more information before making a decision leads to another choice: whether to seek that information or to wait for it to present itself. One could conduct a supplementary study to get the needed information ("looking before you leap"), or, if the situation permits, one could simply wait for the information to present itself ("crossing the bridge when you come to it").

Delaying the decision is one way to wait for information; making contingency plans is another. "If the deer population is reduced by more than 10 percent, such and such mitigating measures will be taken." "If community services are overburdened by more than 5 percent, such and such mitigating measures will be taken." The costs of delay in implementing mitigation measures until such information is available may be less than the cost of seeking the information or of implementing mitigation measures that turn out not to have been needed. Both delaying the decision and making contingency plans have the effect of "keeping your options open".

Relying on contingency plans becomes less attractive, however, when potential adverse impacts are irreversible. Uncertainty about dam safety, for example, must be reduced to a very low level before the decision to build a dam is made. The appropriateness of a decision to seek information or to wait for it to appear thus clearly depends on the nature of the impacts in question.

Analytic techniques are available for evaluating the cost-effectiveness of obtaining further information (Raiffa, 1968; Brown, Kahr, & Peterson, 1974.) These techniques are beyond the scope of the present treatment and require expert consultation. However, one simple procedure (Byer & Saunders, 1979) for deciding whether it is worthwhile to gather data for a given dimension is to translate the maximum difference that perfect knowledge about the dimension might make in the overall evaluation into its monetary equivalent and compare that with the estimated cost of obtaining the data.

Note that the practice of conducting a main study, performing a sensitivity analysis on the results, and then conducting a supplementary study that is directed toward obtaining precisely the information that is most needed for the decision (a "breadth-first/depth-later" strategy of information search) can be highly cost-effective (see de Groot, 1965; Wicklegren, 1974). Because one often does not know what information is needed until one has gone about collecting information, collecting information in stages can turn hindsight into foresight. The Appraisal Study/Feasibility Study/Definite Plan Report sequence capitalizes on this principle. The same principle can also be applied within a study, by means of a scoping/main study/supplementary study sequence.

Risk and the Evaluation of Uncertainty

In virtually all Federal water resources planning, considerable residual uncertainties remain at the time the decision must be made. Some may have been reduced by obtaining added information; and it may have been possible to deal with some by redesigning alternatives or by delaying portions of the decision until additional information becomes available. Yet much remains, and the decision must be made. In this uncertain world, one can not avoid taking risks altogether.

Uncertainty, itself, has value, which is usually negative. Most people would prefer to avoid uncertainty if at all possible. Consider a choice between the following alternatives.

Alt. 1: Do not bet (and gain $0 for certain).

Alt. 2: Bet $1000 on the toss of a coin (and gain $1000 with a probability of .50 and lose $1000 with a probability of .50.)

Most people would prefer not to make such a bet; they would prefer Alternative 1. The best point estimate of the amount to be gained in each case is $0. [.50(+$1000) + .50(-$1000) = 0.] The only difference between these alternatives is in the range of possible outcomes, $0 for certain vs. $0 +/- $1000.

This example differs from the situations faced in Federal water resources decisions in that the risky alternative offers no benefits in comparison with the riskless alternative. The following example comes one step closer to the reality of Federal water resources planning by incorporating such a benefit.

Alt. 1: Gain $0 for certain.

Alt. 2: Lose $500 with a probability of .50 and gain $1500 with a probability of .50.

Here there is a tradeoff between the positive value of an expected gain of $500 [.50(-$500) + .50(+$1500) = +$500] and the the negative value of the uncertainty associated with this gain.

To clarify this further, consider a third example.

Alt. 1: Gain $0 for certain.

Alt. 2: Gain $500 for certain.

In the first example, the two alternatives differed only with respect to uncertainty, and Alternative 1 was clearly the more preferred. In this third example, the two alternatives differ only with respect to expected gain, and Alternative 2 is clearly the more preferred. It is the second example that is closest to the reality of Federal water resources decisions, for both factors are involved, and whether Alternative 1 or Alternative 2 is preferred depends on one's value tradeoffs.

(All these examples differ from the situations faced in Federal water resources decisions in that, in Federal water resources decisions, it is usually the case that all alternatives involve some risk, though perhaps on different dimensions. For example, building a dam may involve risks to the environment yet at the same time reduce risks due to flooding and drought.)

There are two ways, beyond the dominance screening step described at the end of Chapter 6, to take the value of uncertainty into account in planning decisions. One is to employ a technique known as utility assessment and to maximize expected utility (Brown, Kahr, & Peterson, 1974; Keeney & Raiffa, 1976.) In principle, utility assessment could be applied to obtain the values of the impacted publics. However, this seems never to have been done, and for good reason. The highly sophisticated technique required would seem to be too complex and time-consuming to be applied to large samples of the public.

The other way to take the value of uncertainty into account in planning decisions, and the way being recommended here, is (a) to carry the analysis forward to the point of aggregating across publics without taking risk into account and then (b) to attempt to make appropriate intuitive adjustments to the results of the across-publics analysis. Utility assessment could be employed at this point to aid the key decision makers. This is quite feasible. It has been done in a number of contexts; and it would seem to be the best way to proceed. However, utility assessment should not be attempted without expert consultation. A detailed consideration of utility assessment techniques is beyond the scope of the present treatment.

Intuitive adjustments for the negative value of uncertainty can be made without the aid of utility assessment, and it may be better that such adjustments be made intuitively than that they not be made at all. If one or more alternatives can be identified as more risky than the others, their value can be adjusted downwards. The one thing most people would agree with is that the true value of a risky alternative is lower than that indicated by an assessment which has not taken risk into account. It should be noted, however, that not all take the view that the principle of risk aversion can be generalized to public policy decisions. (See Arrow, 1967; Stokey & Zeckhauser, 1978, p. 252).

Chapter 8: PRESENTATION of the RESULTS

Only those results that are reported can have any chance of influencing the decision, and only those results that are correctly understood can have any reasonable chance of influencing the decision in an appropriate direction. From a practical point of view, an analysis is no better than the report of it. Three qualities are especially desirable in the report of an analysis: relevance, redundancy, and retraceability.

Relevance

The report should begin with an executive summary which includes only the most relevant material and should have an appendix for the least relevant material. Such a division gives the reader some control over the relevance of the material he/she reads.

Only information that bears on *differences* among alternatives is directly relevant to the decision. The *Principles & Standards* (1973, p. 16) states that "The display of beneficial and adverse effects for each alternative plan will be prepared so that the differences among alternatives can be clearly shown and accurately analyzed." Since one of the alternatives is the no plan alternative, it is appropriate to require also (p. 10) that "Beneficial and adverse effects of each alternative plan will be determined by comparing the conditions expected with the plan to the conditions expected without the plan." All tables and graphs should include the decision variable, that is, the dimension whose levels are the various alternatives under consideration. Ideally, also, all tables and graphs will include a publics variable, a dimension whose levels are the various impacted publics. In addition, attention to the results of sensitivity analyses can help to focus the presentation on those factors that are critical.

Redundancy

Redundancy means saying the same thing again. The executive summary and the main body of the report do this in a very direct way. However, it is more useful, in saying the same thing again, to say it in different ways. Numerical, graphic, and verbal means should all be employed. The logical framework of the analysis is quantitative, and so it is essential that scale values, weights, and aggregated values be presented. However, most people have difficulty with numbers. All important quantitative results should also be presented graphically, and by means of graphs that are as self-explanatory as possible. In addition, all graphs should be fully explained in the text. A good test to apply to the report of an analysis is to ask the following questions:

1. Can a person look at just the tables and understand the report?
2. Can a person look at just the graphs and understand the report?

3. Can a person read just the text and understand the report?

If the answer to all three questions is "yes", the report should be an unusually clear one.

The text should also introduce redundancy by dealing with material at both abstract and concrete levels. General relationships must be stated, but, in addition, their concrete meaning should be illustrated as clearly as possible with examples and "quotable quotes". "Quotable quotes" are more readily understood and remembered than numbers (Abelson, 1976; Tversky & Kahneman, 1977; Nisbett, Borgida, Crandall, & Reed, 1976); however, "quotable quotes" must be selected only to illustrate conclusions justified by the numbers. Also, critical values should be anchored to experientially meaningful referents, such as the present conditions value, just as was done for the respondents from whom value judgments were obtained. The reader of the report will also be making value judgments, and *the same principles that apply to helping representatives of the public to make sound value judgments also apply to helping decision makers to make sound value judgments.*

The basic framework for tabular presentation of data consists of three types of tables. The first presents impacts, measured in objective, uncommensurated terms.

Table 8.1: Impacts for One Public
(farmers)

	Income	Population	Percent Middle Class
No Plan	83779	2288	36
Plan I	114460	2545	36
Plan II	72463	3076	54

The second presents, for each public, impacts commensurated within publics.

Table 8.2: Evaluation of Impacts,
Commensurated Within a Public
(farmers)

	Income	Population	Middle Class	V*
Plan I	6	2	4	12
Plan II	1	14	7	22

The third presents, for each weighting scheme, impacts commensurated across publics and weighted.

Table 8.3: Evaluation of Impacts,
Commensurated Across Publics
(linear utility curve, equal *Nj*'s)

	Farmers	Workers	Community	*SV*
Plan I	12	13	11	7.84
Plan II	22	19	8	14.74

Retraceability

Retraceability is the requirement that the report enable the reader to recover the logic by which the conclusions of the analysis were reached. A good test for retraceability is the following question:

> Could someone else repeat the entire analysis on the basis of this description?

The important aspects of retraceability for most decision makers have to do with (a) describing the precautions taken to avoid biases in sampling the publics, selecting the dimensions, and obtaining judgments from the respondents; and (b) breaking down the results by public and by dimension. Technical considerations should be included, but they should be placed in an appendix, since they will be of interest to only a limited audience.

Another good test is to ask for each statement that is in the nature of a conclusion:

> Has it been made clear how this statement is justified by the data?

Every conclusion should either be based directly on data or follow closely from statements that are based directly on data.

A fact that makes retraceability especially important where commensuration is involved is that commensuration throws away information. While commensurated figures reveal, they also conceal. For example, while a commensurated value of "6" on the income dimension is more meaningful to a decision maker than an income of $114,460 in that it makes clear how important the impact on this dimension is relative to impacts on other dimensions, the dollar amount is more meaningfully in relation to the decision maker's personal experience. Since the decision maker has little in the way of an intuitive base for evaluating the results of the commensuration process, it is important to provide an "audit trail", so he/she can retrace the steps involved in commensuration and evaluate the process, itself, analytically. It is also important to begin this trail at a point that will be intuitively meaningful to the decision maker.

The presentation of the analysis should be sufficiently open to provide the decision maker with a sound basis for forming an independent opinion about each of the major steps in the analysis and for making allowances for what he/she may consider to be errors. *The report of the analysis should not only (a) provide a sound starting point for the decision maker's final judgment, but also (b) provide information that can help the decision maker to decide in what direction and how far to adjust from this starting point.* In this way, the report will be a genuine decision aid, and not simply the report of a decision.

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APPENDIX

```
00100 print "CALCULATION of UTILITIES"
00110 print "on BASIS of TWO-SEGMENT CURVES"
00120 print "..............................."
00130 print
00140 dim b(10)
00150 dim o(50)
00160 dim z(50)
00170 let i=1
00180 let j=1
00190 print "Enter units (e.g., dollars) on objective dimension."
00200 input u$
00210 print "Enter low value on objective dimension."
00220 input l
00230 print "Enter high value on objective dimension."
00240 input h
00250 print "Enter utility level of inflection point."
00260 input u
00270 if u>9 then 00320
00280 if u>0 then 00350
00290 print "Utility level of inflection point"
00300 print "must be within the range 1 to 9 inclusive."
00310 go to 00250
00320 print "Utility level of inflection point"
00330 print "must be within the range 1-9 inclusive."
00340 go to 00250
00350 print "Enter objective level of inflection point."
00360 for i=1 to 10
00370 input b(i)
00380 if b(i)=999 then 00720
00390 if b(i)>h then 00410
00400 if b(i)>=l than 00440
00410 print "Objective level of inflection point"
00420 print "must be within the range";l;"-";h;"inclusive."
00430 go to 00350
00440 let w1=u/(b(i)-l)
00450 let w2=(10-u)/(h-b(i))
00460 print "Enter objective value for which"
00470 print "utility is desired."
00480 input o(j)
00490 if o(j)=999 then 00680
00500 if o(j)>h then 00520
00510 if o(j)>=l then 00550
00520 print "Objective value must be within"
00530 print "the range";l;"-";h;"inclusive."
00540 go to 00460
00550 let d=o(j)-b(i)
00560 if d>0 then 00590
00570 let z(j)=w1*(o(j)-l)
00580 go to 00620
00590 let m=w1*(b(i)-l)
00600 let n=w2*(o(j)-b(i))
00610 let z(j)=m+n
00620 print "-> utility of";o(j);u$;"=";z(j)
```

```
00630 let c(i)=j
00640 let j=j+1
00650 print "Enter next objective value."
00660 print "If no more objective values, enter 999."
00670 go to 00480
00680 print "Enter next objective level of inflection point."
00690 print "If no more inflection points, enter 999."
00700 let k=i
00710 next i
00720 print "Would you like the results tabulated?"
00730 print "Y or N?"
00740 input a$
00750 if a$="n" then 00900
00760 if a$="y" then 00800
00770 go to 00730
00780 print
00790 print
00800 let i=1
00810 let j=0
00820 for i=1 to k
00830 print
00840 print "UTILITIES where";u;"=";b(i);u$
00850 let j=j+1
00860 print " ";o(j);u$;" ";z(j)
00870 if j=c(i) then 00890
00880 go to 00850
00890 next i
00900 end
```

BIBLIOGRAPHY

Abelson, R. P. Script processing in attitude formation and decision making. In J. S. Carroll & J. W. Payne (Eds.), *Cognition and Social Behavior*. Potomac, MD: Erlbaum, 1976.

Allison, G. T. *Essence of Decision: Explaining the Cuban Missile Crises*. Boston: Little, Brown, 1971.

Anderberg, M. R. *Cluster Analysis for Applications*. New York: Academic Press, 1973.

Anderson, B. F., Deane, D. H., Hammond, K. R., McClelland, G. H., & Shanteau, J. *Concepts in Judgment and Decision Making: Definitions, sources, interrelations, comments*. New York: Praeger, 1981.

Anderson, N. H. Information integration theory: A brief survey. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.), *Contemporary Developments in Mathematical Psychology* (Vol. 2) San Francisco: Freeman, 1974.

Arrow, K. J. *Social Choice and Individual Values*. New York: Wiley, 1951.

Arrow, K. J. *Social Choice and Individual Values*. (2d ed.) New York: Wiley, 1963.

Arrow, K. J. Discussion Paper No. 2. Resources for the Future Seminar on the Discount Rate for Public Investment. Washington, D. C.: March, 1965. (mimeo.)

Arrow, K. J. Extended sympathy and the possibility of social choice. *Philosophia*, 1978, 7, 223-238.

Arrow, K. J., & Lind, R. C. Uncertainty and the evaluation of public investment decisions. *American Economic Review*, 1968, 60, 364-378.

Attneave, F. *Applications of Information Theory to Psychology*. New York: Holt, 1959.

Ajzen, I., & Fishbein, M. Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychological Bulletin*, 1977, 84, 888-918.

Baird, J. C., & Noma, E. *Fundamental's of Scaling and Psychophysics*. New York: Wiley, 1978.

Bishop, A. B., McKee, M., Morgan, T., & Narayan, R. Multiobjective planning: Concepts and methods. *ASCE Proceedings, Journal of Water Resources Planning and Management Division*, 1976, 102, 239-253.

Black, D. On the rationale of group decision making. *Journal of Political Economy*, 1948, 56, 23-34.

Black, D. The decisions of a committee using a special majority.

BEST DOCUMENT AVAILABLE

Econometrica, 1948, 16, 245-261.

Broadbent, D. E. The magic number seven after fifteen years. In A. Kennedy & A. Wilkes (Eds.), *Studies in Long Term Memory*. New York: Wiley, 1975. Pp. 3-18.

Brown, C. A., Quinn, R. J., & Hammond, K. R. *Scaling Impacts of Alternative Plans*. Boulder, Colorado: Center for Research on Judgment and Policy, University of Colorado, 1980. (Contract No. 8-02407 with Water and Power Resources Service.

Byer, P. H., & Saunders, D. Choosing objectives in transportation planning. *ASCE Proceedings, Transportation Engineering Journal*, 1979, 105, 91-103.

Campbell, A., Converse, P. E., Miller, W. E., & Stokes, D. E. *The American Voter*. (An abridgment.) New York: Wiley, 1964.

Cohon, J. L. *Multiobjective Programming and Planning*. New York: Academic Press, 1978.

Cohon, J. L., & Marks, D. H. A review and evaluation of multiple objective programming techniques. *Water Resources Research*, 1975, 11, 208-220.

Comrey, A. L. A proposed method for absolute ratio scaling. *Psychometrika*, 1950, 15, 317-325.

Crawford, R. P. *Techniques of Creative Thinking*. New York: Hawthorn, 1954.

Crawford, R. P. *Direct Creativity with Attribute Listing*. Burlington, Vt.: Fraser, 1964.

Creighton, J. L. *Alternative Futures Planning*. Denver, CO: U. S. Bureau of Reclamation, 1976.

Cronbach, L. J. Response sets and test design. In D. A. Payne & R. F. McMorris (Eds.), *Educational and Psychological Measurement: Contributions to theory and practice*. Waltham, Mass.: Blaisdell, 1967. Pp. 186-197.

Dahl, R. A. A *Preface to Democratic Theory*. Chicago, Ill.: University of Chicago Press, 1956.

Dawes, R. M., & Corrigan, B. Linear models in decision making. *Psychological Bulletin*, 1974, 81, 95-106.

deGroot, A. D. *Thought and Choice in Chess*. The Hague: Mouton, 1965.

DeSoto, C. B. Learning a social structure. *Journal of Abnormal and Social Psychology*, 1960, 60, 417-421.

DeSoto, C. B. The predilection for single orderings. *Journal of Abnormal and Social Psychology*, 1961, 62, 16-23.

Dorfman, R. Conceptual model of a regional water quality authority.

In R. Dorfman, H. D. Jacoby, & H. A. Thomas, Jr. (Eds.), *Models for Managing Regional Water Quality*. Cambridge, Mass.: Harvard University Press, 1972.

Dorfman, R., & Jacoby, H. D. An illustrative model of river basin pollution control. In R. Dorfman, H. D. Jacoby, & H. D. Thomas, Jr. (Eds.), *Models for Managing Regional Water Quality*. Cambridge, Mass.: Harvard University Press, 1972.

Easton, A. *Complex Managerial Decisions Involving Multiple Objectives*. New York: Wiley, 1973.

Edwards, E. How to use multiattribute utility measurement for social decisionmaking. *IEEE Trans. Systems, Man, & Cybernetics*, 1977, SMC-7, 326-340.

Festinger, L. *A Theory of Cognitive Dissonance*. Evanston, Ill.: Row, Peterson, 1957.

Fischer, G. W. Experimental applications of multiattribute utility models. In D. Wendt & C. Vlek (Eds.), *Utility, Probability, and Human Decision Making*. Dordrecht, Holland: Reidel, 1975. Pp. 7-46.

Fischer, G. W. Convergent validation of decomposed multi-attribute assessment procedures for risky and riskless decisions. *Organizational Behavior and Human Performance*, 1977, 18, 295-315.

Fishburn, P. C. Methods of estimating additive utilities. *Management Science*, 1967, 13, 435-453.

Fishburn, P. C. A survey of multiattribute multicriterion evaluation theories. In S. Zionts (Ed.), *Multiple Criteria Problem Solving*. Buffalo, N. Y.: Springer-Verlag, 1978.

Fitzsimmons, S. J., Stuart, L. I., & Wolff, C. P. (Eds.) *Social Assessment Manual: A guide to the preparation of the Social Well-Being Account for planning water resource projects*. Stroudsburg, Pa.: Hutchinson & Ross, 1977.

Flood, M. M. Let's redesign democracy. *Behavioral Science*, 1978, 23, 429-440.

Gabrielli, W. F., Jr., & von Winterfeldt, D. *Are importance weights sensitive to the range of alternatives in multiattribute measurement?* Social Science Research Institute Report No. 78-6. Los Angeles, Calif.: University of Southern California, 1978.

Gardiner, P. C., & Edwards, W. Public values: Multiattribute utility measurement for social decision making. In M. F. Kaplan & S. Schwartz (Eds.), *Human Judgment and Decision Processes*. New York: Academic Press, 1975. Pp. 1-38.

Garner, W. R. *Uncertainty and Structure as Psychological Concepts*. New York: Wiley, 1962.

Ghiselin, B. *The Creative Process*. Berkeley, Calif.: University of California Press, 1952.

Gilmartin, K. J., Rossi, R. J., Lutomski, L. S., & Reed, D. F. B. *Social Indicators: An annotated bibliography of current literature*. New York: Garland, 1979.

Goldberg, L. Diagnosticians vs. diagnostic signs: The diagnosis of psychosis vs. neurosis from the MMPI. *Psychological Monographs*, 1965, 79 (Whole No. 602).

Goldberg, L. R. Man versus model of man: A rationale, plus some evidence, for a method of improving on clinical inferences. *Psychological Bulletin*, 1970, 73, 422-432.

Goodman, L., On methods of amalgamation. In M. R. Thrall, C. Coombs, and R. Davis (Eds.), *Decision Processes*. New York: Wiley, 1959.

Goodman, L. A., & Markowitz, H. Social welfare functions based on individual rankings. *American Journal of Sociology*, 1952, 57, 257-262.

Gordon, W. J. J. *Synectics: The development of creative capacity*. New York: Harper & Row, 1961.

Gordon, W. J. J. *The Metaphorical Way*. Cambridge, Mass.: Porpoise Books, 1971.

Gross, S. J., & Niman, C. M. Attitude-behavior consistency: A review. *Public Opinion Quarterly*, 1975, 39, 358-368.

Guilford, J. P. *Psychometric Methods*. New York: McGraw-Hill, 1954.

Gum, R. L., Roefs, R. G., & Kimball, D. B. Quantifying social goals: Development of a weighting methodology. *Water Resources Research*, 1976, 12, 167-622.

Haimes, Y. Y., & Hall, W. A. Multiobjectives in water resources systems analysis: The Surrogate Worth Trade Off method. *Water Resources Research*, 1974, 10, 615-624.

Hammond, K. R., & Adelman, L. Science, values, and human judgment. *Science*, 1976, 194, 389-396.

Harsanyi, H. C. Cardinal welfare, individualistic ethics, and interpersonal comparisons of utility. *Journal of Political Economy*, 1955, 63, 309-321.

Harsayni, H. C. Morality and the theory of rational behavior. *Social Research*, 1977, 44, 623-656.

Hicks, J. R. The foundations of welfare economics. *Economic Journal*, 1939, 49, 696-712.

Hildreth, C. Alternative conditions for social ordering. *Econometrica*, 1953, 21, 81-95.

Hobbes, B. F. *Analytical multiobjective decision methods for power plant siting: A review of theory and applications*. Upton, N. Y.: Brookhaven National Lab., 1979. (Prepared for the U. S. Nuclear

Regulatory Commission.)

Hoepfl, R., & Huber, G. A study of self-explicated utility models. *Behavioral Science*, 1970 (Sept.)

Hoffman, P., Slovic, P., & Rorer, L. G. An analysis-of-variance model for the assessment of configural cue utilization in clinical judgment. *Psychological Bulletin*, 1968, 69, 338-349.

Huber, G. P. Methods for quantifying subjective probabilities and multi-attribute utilities. *Decision Sciences*, 1974a, 5, 430-458.

Huber, G. P. Multiattribute utility models: A review of field and field-like studies. *Management Science*, 1974b, 20, 1393-1402.

Janis, I. L., & Mann, L. *Decision Making: A psychological analysis of conflict, choice, and commitment*. New York: The Free Press, 1977.

Kahneman, D., & Tversky, A. Subjective probability: A judgment of representativeness. *Cognitive Psychology*, 1972, 3, 430-454.

Kahneman, D., & Tversky, A. On the psychology of prediction. *Psychological Review*, 1973, 80, 237-251.

Kaldor, N. Welfare propositions of economics and interpersonal comparisons of utility. *Economic Journal*, 1939, 49, 549-552.

Kawamura, K., & Malone, D. W. Probing complexity in social systems through interpretive structural modeling. In K. Finsterbusch & C. P. Wolf (Eds.), *Methodology of Social Impact Assessment*. Stroudsburg, PA: Dowden, Hutchinson, & Ross, 1977. Pp. 347-354.

Keeney, R. L. Utility functions for equity and public risk. *Management Science*, 1980, 26, 345-353.

Keeney, R. L., & Nair, K. Selecting nuclear power plant sites using decision analysis. In. D. E. Bell, R. L. Keeney, & H. Raiffa (Eds.), *Conflicting Objectives in Decisions*. New York: Wiley, 1977.

Keeney, R. L., & Raiffa, H. *Decisions with Multiple Objectives: Preferences and value trade-offs*. New York: Wiley, 1976.

Keeney, R. L., & Wood, E. F. An illustrative example of the use of multiattribute utility theory for water resource planning. *Water Resources Research*, 1977, 13, 705-712.

Kish, L. *Survey Sampling*. N. Y.: Wiley, 1965.

Kung, H. On the computational complexity of finding the maxima of a set of vectors. *Proceedings of the 15th Annual IEEE Symposium on Switching and Automatic Theory*, Oct. 1974, pp. 117-121.

Lecky, P. *Self-Consistency: A theory of personality*. New York: Island Press, 1945.

Levin, I. P., Kim, K. J., & Corry, F. A. Invariance for the weight parameter in information integration. *Memory and Cognition*, 1976, 4, 43-47.

Lichtenstein, S., Fischhoff, B., & Phillips, L. D. Calibration of probabilities: The state of the art. In H. Jungermann & G. deZeew (Eds.), *Decision Making and Change in Human Affairs*. Dordrecht, Holland: Reider, 1977. Pp. 275-324.

Linstone, H., & Turoff, M. *The Delphi Method: Techniques and applications*. Reading, Mass.: Addison-Wesley, 1975.

Little, I. M. D. *Critique of Welfare Economics*. (2d ed.) Oxford: Clarendon, 1957.

Lord, W. B., Adelman, L., Wehr, P., Brown, C., Crews, R., Marvin, B., & Waterstone, M. *Conflict Management in Federal Water Resource Planning*. Program on Technology, Environment and Man, Monograph No. 28. Boulder, CO: University of Colorado, 1979.

Lord, W. B., Deane, D. H., & Waterstone, M. *Commensuration in Federal Water Resources Planning: Problem Analysis and Research Appraisal*. Boulder, Colorado: L T W Associates, 1979 (Research Report 79-2 for the Bureau of Reclamation.)

Lowi, T. J. Four systems of policy, politics, and choice. *Public Administration Review*, 1972, 32, 298-.

Luce, R. D., & Raiffa, H. *Games and Decisions: Introduction and critical survey*. New York: Wiley, 1957. Ch. 14.

MacCrimmon, K. R. An overview of multiple objective decision making. In J. Cochrane & M. Zeleny (Eds.), *Multiple Criteria Decision Making*. Columbia, S. C.: U. of South Carolina Press, 1973. Pp. 18-44.

MacCrimmon, K. R., & Siu, J. Making tradeoffs. *Decision Sciences*, 1974, 5, 680-704.

Major, D. C. Benefit-cost ratios for projects in multiple objective investment programs. *Water Resources Research*, 1969, 5, 1174-1178.

McClelland, G. H. *Equal versus differential weighting for multiattribute decisions: There are no free lunches*. Center for Research on Judgment and Policy Report No. 207. Boulder, Colo.: University of Colorado, 1978.

McClelland, G. H., & Rohrbaugh, J. *Who accepts the Pareto axiom? The role of utility and equity in arbitration decisions*. Center for Research on Judgment and Policy Report No. 202. Boulder, Colol.: University of Colorado, 1977.

McKim, R. H. *Experiences in Visual Thinking*. Monterey, Calif.: Brooks/Cole, 1972.

Metfessel, M. A proposal for quantitative reporting of comparitive judgments. *Journal of Psychology*, 1949, 24, 229-235.

Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information *Psychological*

Review, 1956, 63, 81-97.

Mishan,, E. J. The economics of disamenity. *Natural Resources Journal*, 1974, 14, 55-86.

Mishan, E. J. How valid are economic evaluations of allocative changes? *Journal of Economic Issues*, 1980, 14, 143-161.

Mumpower, J., & Bollacker, L. *Evaluation and Sensitivity Analysis Program (ESAP). Appendix I: User's Manual*. Boulder, Colo.: Center for Research on Judgment and Policy, University of Colorado, 1980. (Prepared for the U. S. Army Corps of Engineers.)

Mumpower, J., Stewart, T., Anderson, B., Brown, C., Cook, R. L., Crumpacker, W., & Wascoe, N. *A Report to the U. S. Water Resources Council on the Forecasting, Assessment, and Evaluation of Environmental Impacts*. Center for Research on Judgment & Policy, Boulder, CO: University of Colorado, 1979.

National Goals Research Staff. *Toward Balanced Growth: Quantity with quality*. Washington, D. C.: U. S. Government Printing Office, 1970.

Newell, A., & Simon, H. A. *Human Problem Solving*. Englewood Cliffs, N. J.: Prentice-Hall, 1972.

Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., & Bent, D. H. *SPSS: Statistical Package for the Social Sciences*. (2d ed.) New York: McGraw-Hill, 1975.

Nisbett, R. E., Borgida, E., Crandall, R., & Reed, H. Popular induction: Information is not always informative. In J. Carroll & J. Payne (Eds.), *Cognition and Social Behavior*. Potomac, MD: Erlbaum, 1976.

Olsen, M. E., & Merwin, D. J. Toward a methodology for conducting social impact assessments using quality of social life indicators. In K. Finsterbusch & C. P. Wolff (Eds.), *Methodology of Social Impact Assessment*. Stroudsburg, Pa.: Dowden, Hutchinson, & Ross, 1977.

Ortolano, Brendecke, Price, & Meersman. *Environmental considerations in three infrastructure planning agencies: An overview of research findings*. Report IPM-6. Program in Infrastructure Planning and Management, Department of Civil Engineering. Stanford: Stanford U., December, 1978.

Osborn, A. F. *Applied Imagination: Principles and procedures of creative problem solving* (3d rev ed.) New York: Scribner's Sons, 1963.

Page, T. *Conservation and Economic Efficiency*. Baltimore: The Johns Hopkins U. Press, 1973.

Parducci, A. Range-frequency compromise in judgment. *Psychological Monographs*, 1963, 77 (Whole No. 565).

Parducci, A. Category judgment: A range-frequency model. *Psychological Review*, 1965, 72, 407-418.

Parducci, A. The relativism of absolute judgments. *Scientific American*, 1968, 219, No. 6, 84-93.

Pareto, V. *Manual of Political Economy*. New York: A. M. Kelley, 1971 (originally published in 1927).

Peterson, G. L., & Gemmell, R. S. Social impact assessment: Comments on the state of the art. In K. Finsterbusch & C. P. Wolf (Eds.), *Methodology of Social Impact Assessment*. Stroudsburg, PA: Dowden, Hutchinson, & Ross, 1977. Pp. 374-387.

Plott, C. R. Axiomatic social choice theory: An overview and interpretation. *American Journal of Political Science*, 1976, 20, 511-596.

Poincare, H. Mathematical creation. In G. B. Halstead (Transl.), *Foundations of Science*. New York: Science Press, 1913.

Polya, G. *How to Solve It*. Garden City, N. Y.: Doubleday Anchor, 1957.

President's Commission on National Goals. *Goals for Americans*. New York: Columbia University, 1960.

Raiffa, H. *Decision Analysis: Introductory lectures on choices under uncertainty*. Reading, Mass.: Addison-Wesley, 1968.

Rawls, J. *A Theory of Justice*. Cambridge, Mass.: Harvard University Press, 1971.

Schaumburg, G. *The Paretian model: Public decision making in the face of conflicting interests*. Disc. Paper No. 73-2, Environmental Systems Program, Harvard University, Cambridge, Mass., 1973.

Sen, A. *On Economic Inequality*. New York: Norton, 1973.

Shanteau, J. *The concept of weight in judgment and decision making: A review and some unifying proposals*. Center for Research on Judgment and Policy, Report No. 228. Boulder, CO: University of Colorado, 1980.

Shepard, R. N. On subjectively optimal selections among multiattribute alternatives. In M. Shelley & G. Bryan (Eds.), *Human Judgments and Optimality*. New York: Wiley, 1964. Pp. 257-281.

Silviera, J. *Incubation: The effect of interruption timing and length on problem solution and quality of problem processing*. Eugene, Ore.: University of Oregon, 1971 (Unpublished doctoral dissertation).

Sinden, J. A., & Worrell, A. C. *Unpriced Values: Decisions without market prices*. New York: Wiley, 1979.

Slovic, P., Fleissner, D., & Bauman, W. S. Analyzing the use of information in investment decision making: A methodological proposal. *Journal of Business*, 1972, 45.

Slovic, P., & Lichtenstein, S. Comparison of Baysian and regression approaches to the study of human information processing in judgment. *Organizational Behavior and Human Performance*, 1971, 6, 649-744.

Slovic, P., Lichtenstein, S., & Edwards, W. Boredom-induced changes in preferences among bets. *The American Journal of Psychology*, 1965, 78, 208-217.

Som, R. K. *A manual of Sampling Techniques*. London: Heinemann, 1973.

Spetzler, C. S., & Stael von Holstein, C.-A. Probability encoding in decision analysis. *Management Science*, 1975, 22, 340-358.

Stein, M. I. *Stimulating Creativity: Individual procedures*. Vol. I. New York: Academic Press, 1974.

Stein, M. I. *Stimulating Creativity: Group procedures*. Vol. II. New York: Academic Press, *1975*.

Steiner, P. D. *Public Expenditure Budgeting*. Washington, D. C.: The Brookings Institute, 1967.

Stineman, R. W. A consistently well-behaved method of interpolation. *Creative Computing*, July 1980, 54-57.

Stokey, E., & Zeckhauser, R. *A Primer for Policy Analysis*. New York: Norton, 1978.

Technical Committee of the Water Resources Centers of the Thirteen Western States. *Water Resources Planning and Social Goals: Conceptualization toward a new methodology*. (Prepared for the Office of Water Resources Research.) Water Research Laboratory Publication PRWG-94-1. Logan, Utah: Utah State University, 1971.

Torgerson, W. S. *Theory and Methods of Scaling*. New York: Wiley, 1965.

Tversky, A. On the elicitation of preferences: Descriptive and prescriptive considerations. In D. E. Bell, R. L. Keeney, & H. Raiffa (Eds.), *Conflicting Objectives in Decisions*. New York: Wiley, 1977. Pp. 209-219.

Tversky, A., & Kahneman, D. Belief in the law of small numbers. *Psychological Bulletin*, 1971, 76, 105-110.

Tversky, A., & Kahneman, D. Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 1973, 5, 207-232.

Tversky, A., & Kahneman, D. Judgment under uncertainty: Heuristics and biases. *Science*, 1974, 185, 1124-1131.

Tversky, A., & Kahneman, D. Causal schemata in judgments under uncertainty. In M. Fishbein (Ed.), *Progress in Social Psychology*. Hillsdale, N. J.: Erlbaum, 1977.

von Neumann, J., & Morgenstern, O. *Theory of Games and Economic Behavior*, 2d ed. Princeton, N. J.: Princeton University Press, 1947.

Warfield, J. N. *An Assault on Complexity*. Columbus, Ohio: Battelle Memorial Institute, 1973.

Wason, P. C., & Johnson-Laird, P. N. *Psychology of Reasoning*. Cambridge, Mass.: Harvard University Press, 1972.

Water Resources Council. *Principles and Standards for Planning Water and Related Land Resources*. Washington, D. C.: U. S. Government Printing Office, 1973.

Webb, E. J., Campbell, D. T., Schwartz, R. D., & Sechrest, L. *Unobtrusive Measures: Nonreactive research in the social sciences*. Chicago: Rand McNally, 1966.

Whiting, *C. S.* Creative Thinking. *New York: Reinhold, 1958*.

Whitman, I., Dee, N., et al. *Design of an Environmental Evaluation System Final Report*. Columbus, Ohio: Battelle Laboratories, 1971. (Prepared for the U. S. Bureau of Reclamation.)

Wicker, A. W. Attitudes versus actions: The relationship of verbal and overt behavioral responses to attitude objects. *Journal of Social Issues*, 1969, 25, 41-78.

Wicklegren, W. A. *How to Solve Problems*. San Francisco: Freeman, 1974.

Willeke, G. E. Identifying publics in social impact assessment. In K. Finsterbusch & C. P. Wolf (Eds.), *Methodology of Social Impact Assessment*. Stroudsburg, PA: Dowden, Hutchinson, & Ross, 1977. Pp. 317-323.

Wright, P., & Barbour, E. Phased decision strategies: Sequel to an initial screening. In M. K. Starr & M. Zeleny (Eds.), *Multiple Criteria Decision Making*. Amsterdam: North Holland Publishing Co., 1977.

Yntema, D. B., & Torgerson, W. S. Man-computer cooperation in decisions requiring common sense. *IRE Transactions on Human Factors in Electronics*, March 1961, 20-26.

Zionts, S., & Wallenius, J. An interactive programming method for solving the multiple criteria problem. *Management Science*, 1976, 22, 652-663.

Zwicky, F. *Morphological Astronomy*. Berlin: Springer-Verlag, 1957.

Zwicky, F. *Discovery, Invention, Research*. New York: MacMillan, 1969.

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